

UTILITY
PATENT APPLICATION
TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 826.1618/JDH

First Named Inventor or Application Identifier

Noboru TOMOMITSU, et al

Express Mail Label No.

1-2808 U.S. PTO
09/658692

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. Fee Transmittal Form

2. Specification, Claims & Abstract [Total Pages: 89]

3. Drawing(s) (35 USC 113) [Total Sheets: 48]

4. Oath or Declaration [Total Pages: 3]

a. Newly executed (original or copy)

b. Copy from a prior application (37 CFR 1.63(d)) (*for continuation/divisional with Box 17 completed*)

i. DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application,
see 37 CFR 1.63(d)(2) and 1.33(b).

5. Incorporation by Reference (usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. Microfiche Computer Program (*Appendix*)

7. Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all necessary*)

a. Computer Readable Copy

b. Paper Copy (identical to computer copy)

c. Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

- 8. Assignment Papers (cover sheet & document(s))
- 9. 37 CFR 3.73(b) Statement (*when there is an assignee*) Power of Attorney
- 10. English Translation Document (*if applicable*)
- 11. Information Disclosure Statement (IDS)/PTO-1449[1] Copies of IDS Citations
- 12. Preliminary Amendment
- 13. Return Receipt Postcard (MPEP 503) (*Should be specifically itemized*)
- 14. Small Entity Statement(s) Statement filed in prior application, status still proper and desired.
- 15. Certified Copy of Priority Document(s) (*if foreign priority is claimed*) (*Japanese Appln. 11-271916, filed 9/27/99*)
- 16. Other:

17. If a **CONTINUING APPLICATION**, check appropriate box and supply the requisite information

Continuation Divisional Continuation-in-part (CIP) of prior application No: /

18. CORRESPONDENCE ADDRESS



21171

21171

**NEW APPLICATION
FEE TRANSMITTAL**

		Attorney Docket No.	826.1618/JDH
		Application Number	
		Filing Date	
AMOUNT ENCLOSED	\$1036.00	First Named Inventor	Noboru TOMOMITSU, et al.

FEE CALCULATION (fees effective 12/29/99)

CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
TOTAL CLAIMS	24	- 20 =	4	X \$ 18.00 =	\$ 72.00
INDEPENDENT CLAIMS	6	- 3 =	3	X \$ 78.00 =	234.00
MULTIPLE DEPENDENT CLAIMS (any number; if applicable)				+\$260.00 =	
BASIC FILING FEE					690.00
				Total of above Calculations =	\$ 996.00
Surcharge for late filing fee, Statement or Power of Attorney (\$130.00)					+
Reduction by 50% for filing by small entity (37 CFR 1.9, 1.27 & 1.28).					-
TOTAL FILING FEE =					\$ 996.00
Surcharge for filing non-English language application (\$130.00; 37 CFR 1.52(d))					+
Recordation of Assignment (\$40.00; 37 CFR 1.21(h)(1))					40.00
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SUBMITTED BY: STAAS & HALSEY LLP

Typed Name	James D. Halsey, Jr.	Reg. No.	22,729
Signature		Date	September 8, 2000

APPLICATION FOR
UNITED STATES LETTERS PATENT
SPECIFICATION

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Title of the Invention: CAD SYSTEM, CAD COOPERATIVE SYSTEM,
CAD DATA MANAGING METHOD, AND STORAGE
MEDIUM

**CAD SYSTEM, CAD COOPERATIVE SYSTEM, CAD DATA MANAGING
METHOD, AND STORAGE MEDIUM**

Background of the Invention

5 **Field of the Invention**

The present invention relates to a graphic process device such as a CAD system, etc. and a program storage medium storing a program used to realize the graphic process device, and more 10 specifically to a technology of automatically assembling a three-dimensional model, and forming the correspondence among two- and three-dimensional data of a designed plane/space (hereinafter referred to as 'view').

15 **Description of the Related Art**

Recently, common machines and buildings are designed by the CAD system from the step of drawing figures using a drafter.

20 A two-dimensional CAD has been developed as an electronic function of drawing figures which have conventionally been drawn by a drafter (the two-dimensional CAD in the present invention contains an application for drawing the shape of an object 25 referred to as a drawing tool in addition to a common

two-dimensional CAD). The designing process by the two-dimensional CAD is performed while a line drawing process is performed on a two-dimensional plane such as a 3-view figure, etc. When a designing process is 5 performed on the two-dimensional plane, the shape of a part of a unit and the three-dimensional partial placement position are represented separately by a plurality of figures (plane figures) such as a front view, a side view, a sectional view, etc. Therefore, 10 there can be the inconsistent representation of a three-dimensional geometric shape. As a result, the designing process starts with an important portion (important parts and figures) with some parts remaining obscure at the initial stage of the 15 designing process, and the process is gradually performed on detailed portions for consistency. Thus, a flexible designing process can be performed, and the process is frequently adopted.

Figures of machines, etc. come in various sizes 20 such as figures of basic parts, a set of figures used for a combination of parts, figures showing final products, etc. In the two-dimensional CAD, these figures sequentially become large in size by referring to figures of smaller parts.

25 FIG. 1 shows the correspondence of data in the

conventional CAD.

In FIG. 1, views A1, A2, B1, and B2 show the design plane of two-dimensional data, and show the plan view (A1 and B1) and the front view (A2 and B2) of the units A and B. Each of the design planes is configured by referring to other smaller design planes, and the data is hierarchically structured. The data is configured by the link of the data of configuring a design plane of a set of referred-from and referred-to units, and the data of the parts in the smallest unit. For example, the view A1 is configured by the link to the data of the views B1 of a child unit B and C1.

With the proceeding of a designing process on a two-dimensional design plane, a number of editing operations are performed on the placement positions and the shapes of common parts represented in a plurality of figures. However, these editing operations for related process cannot be performed over a plurality of views, and they are limited in improving the design quality and efficiency.

As shown in FIG. 1, in the views of the same unit, there is no information about the correspondence between the two-dimensional design plane A1 and the two-dimensional design plane A2, but the data is

stored as independent in the hierarchical structure. The data of each view is stored in the respective storage files such as a front view, a plan view, etc.

The two-dimensional CAD can have the function of generating a shape of a projection line, etc. as the support function of setting the correspondence between views of a unit, but the function cannot edit the shape over a plurality of views. For example, since the structure of one part cannot be recognized over plural views, graphic data cannot be directly used, but ancillary data has to be generated by a user drawing a figure using a projection line while referring to the views, switching the views, and amending the positions and shapes of the parts to make amendments not only to one view but also to other views when the positions and shapes of a part are amended over a plurality of views.

There has been a system of a hierarchical structure (parentage) of data having a parts structure. However, since there is no structure in which data of each view is related to each other for one unit, each view has an independent hierarchical data structure as shown in FIG. 1. Therefore, when placement positions are amended or a hierarchical structure is generated or changed in one view,

corresponding amending processes are to be made to the data of other views, thereby requiring troublesome operations.

5 In addition, since the three-dimensional CAD for processing a three-dimensional shape of each part or unit as a three-dimensional model can generate a three-dimensionally consistent shape, the resultant design quality can be improved. However, a complicated and intensive process is required to 10 generate and edit (modeling). a three-dimensional model.

15 A three-dimensional design space AS and BS shown in FIG. 1 indicates the three-dimensional work space of the units A and B. For a simple configuration, two-dimensional data is directly converted into the three-dimensional data. However, when a set of figures are processed for a unit formed by several 20 number of parts, a three-dimensional model in a three-dimensional work space is generated by the designer sequentially assembling a three-dimensional model of the smallest part. For example, a three-dimensional model in a three-dimensional design space AS is generated by manually generating a three-dimensional model BS of the unit B after determining the placement 25 position while checking the consistency of the three-

dimensional models DS and ES of the units D and E in the three-dimensional work space, and then combining the three-dimensional model of the unit B with the three-dimensional model CS of the unit C on the three-dimensional work space. In assembling parts, three-dimensional parts have to be placed one by one in the three-dimensional space while setting the conditions for matching in plane, point, axis, etc., thereby requiring a very intensive process when a large three-dimensional parts are assembled. In the example shown in FIG. 1, the number of parts is small, but a set of figures in an actual case may require several thousand parts for which very complicated and intensive operations are performed.

In the designing process performed using the three-dimensional model, parts can be assembled at product level or unit level, and the interference between parts can be confirmed, thereby improving the efficiency in designing (modeling) in part units. However, since the procedure of generating a model indicating the shape of a part is much complicated, and since a consistent shape in a plane view such as a front view, a side view, etc., a designing process for a machine at a designing stage of a set of figures and unit figures in which a plurality of units are

simultaneously designed, a modeling process performed in a complicated procedure lowers the design efficiency.

5 The two-dimensional/three-dimensional cooperative CAD for processing both two-dimensional and three-dimensional data in cooperation has been developed based on the idea of efficiently performing a designing process with the two-dimensional CAD capable of flexibly performing a designing process as 10 necessary or a three-dimensional CAD capable of generating consistent data adopted as necessary to solve the above mentioned problems.

15 However, the current two-dimensional/three-dimensional cooperative CAD does not have the system of generating three-dimensional data used in the three-dimensional CAD by using two-dimensional data used in the two-dimensional CAD, or the system of having two-dimensional data cooperatively used with the three-dimensional data at the parts structure 20 level. Therefore, the cooperation realized by the current two-dimensional/three-dimensional cooperative CAD is only the cooperation system in which non-structured two-dimensional data is transferred to a three-dimensional CAD. Therefore, the current two-dimensional/three-dimensional cooperative CAD is 25

realized only cooperation that the two-dimensional data in the sectional shape for generating three-dimensional data is transferred from a two-dimensional CAD system to a three-dimensional CAD system, two-dimensional data is transferred to a three-dimensional CAD system for using the data as reference data for determining an placement position, and three-dimensional data is developed on a two-dimensional work plane (such as a front view, a side view, or a sectional view, etc.) .

Therefore, although there is electronic data configured using three-dimensional data to assemble a three-dimensional part such as a set of generated figures and/or unit figures, a designer cannot directly utilize this electronic data. Therefore, when a three-dimensional model is generated, the designer displays the data on the screen, assembles them into a three-dimensional part while viewing the screen, or fetches the information about one view to place and move three-dimensional parts one by one.

In addition, during the designing process, a two-dimensional design plane is frequently switched into a three-dimensional design space or vice versa for efficiency, but actually, only the two-dimensional CAD, or the three-dimensional CAD for a detailed

designing part is used at the designing stage.

Thus, the conventional two-dimensional CAD, three-dimensional CAD, and two-dimensional cooperative CAD have the following problems.

5 (1) In the conventional two-dimensional/three-dimensional CAD, when a three-dimensional model is generated based on a set of views or a product figures of a certain scale, three-dimensional data is generated at each part figure level independent of a
10 two-dimensional assembly figures. Then, the designer has to assemble the data in the three-dimensional design space.

(2) A plurality of two-dimensional design planes and three-dimensional design spaces are used for one part,
15 unit, or assembly state. However, the current two-dimensional/three-dimensional CAD does not define the three-dimensional space correspondence for each two-dimensional figure. For example, if each of the three views is individually generated, the name of a view
20 such as a front view, a side view, etc., refers only to the name of a data storage plane, but does not refer to the correspondence between two-dimensional figures such as three views, etc., or between a two-dimensional figure and a three-dimensional model.
25 Furthermore, when a set of three-dimensional figures

are generated, although there are corresponding electronic data such as a corresponding three-dimensional figure, etc., they can only be used as a display reference as reference data, and can not be used directly for assembling a three-dimensional part.

(3) Since there is no correspondence between a two-dimensional design plane and a three-dimensional design space, it is difficult or impossible to frequently switching between the two-dimensional design plane and the three-dimensional design space as necessary during the designing process.

(4) In the three-dimensional CAD, it is a troublesome process to perform an arranging operation on a three-dimensional part.

15 (5) The data of a parts figure can be placed in an assembly figure, but there is no system of recognizing each of the two-dimensional plan view and the three-dimensional model as belonging to one part. Therefore, it is not possible to know how far the influence of figure elements representing one part or unit reaches. Accordingly, the three-dimensional consistency in the correspondence about part position, etc. cannot be managed.

25 Summary of the Invention

Based on the above mentioned problems, the present invention aims at providing a two-dimensional CAD system, a three-dimensional CAD system, a two-dimensional/three-dimensional cooperative CAD system, 5 a cooperative system for realizing the cooperation between CADs, a cooperating method, and a program storage medium for performing the following functions (a) through (e) below.

10 (a) to provide a system for setting the correspondence among a plurality of two-dimensional figures and three-dimensional models for the same part or unit.

15 (b) to provide a system of interlocking the edited contents in a two-dimensional design plane and a three-dimensional design space to another two-dimensional design plane and three-dimensional design space according to the correspondence among two-dimensional design planes and three-dimensional design spaces for the same part or unit, and the information 20 about references.

25 (c) to provide a system of assigning a spatial attribute at a part level to a two-dimensional figure such as a front view, a side view, etc.

(d) to provide an outline for processing plural pieces of plane data such as a front view, a side

view, etc. as a unit when other figure data is referred to.

5 (e) to provide a system for automatically assemble a unit in a three-dimensional shape by generating a spatial correspondence in a three-dimensional shape based on the spatial correspondence of an assembly figure and a part figure generated from the two-dimensional design plane.

10 The present invention is based on the CAD system for processing a two-dimensional design plane/three-dimensional design space configured by referring to a two-dimensional design plane/three-dimensional design space.

15 The CAD system according to the present invention includes an inter-model reference management unit and an intra-model correspondence management unit.

20 The intra-model correspondence management unit manages the correspondence between a two-dimensional design plane and a three-dimensional design space for the same target. The inter-model reference management unit manages the reference information between models configured by a two-dimensional design plane and a three-dimensional design space for the same target.

25 When one of the two-dimensional references or the three-dimensional references between the models is

operated, the inter-model reference management unit
operates another two-dimensional reference or three-
dimensional reference between the models for the above
mentioned operation. Thus, the operation model in a
5 two-dimensional design plane/three-dimensional design
space can be interlocked with another two-dimensional
design plane/three-dimensional design space or another
model. And a plurality of two-dimensional design
planes and/or three-dimensional design spaces
10 belonging to the model can be specified to be edited
based on the correspondence in the model.

In addition, the CAD system can further include
an automatic assembly unit. The automatic assembly
unit generates a three-dimensional reference between
15 the three-dimensional design space of a first model
and the three-dimensional design space of a second
model from the two-dimensional reference of a
plurality of two-dimensional design planes belonging
to the first model to the two-dimensional design plane
20 belonging to the second model, and the correspondence
in the first model and the correspondence in the
second model. In addition, the automatic assembly
unit automatically assembles a three-dimensional
design space belonging to the above mentioned model
25 using the two-dimensional reference of a plurality of

two-dimensional design planes belonging to the same model and the correspondence in the model. The automatic assembly unit automatically assembles a three-dimensional design space having the 5 correspondence in the model and the reference information between the correspondence in the model and the reference information to another model.

In addition, the present invention includes not only a CAD system, but also a cooperative system for 10 cooperatively processing graphic data between the two-dimensional CAD and the three-dimensional CAD, a CAD data managing method, a program storage medium.

According to the present invention, a three-dimensional design space with another model can be 15 automatically set. Therefore, a three-dimensional design space configured by a plurality of elements can be automatically assembled. Furthermore, the three-dimensional design space has the correspondence with the two-dimensional design plane in the same model and the three-dimensional reference with another model. 20 As a result, the operation in a two-dimensional design plane/three-dimensional design space can be reflected by another two-dimensional design plane/three-dimensional design space in the model or another 25 model.

Brief Description of the Drawings

FIG. 1 shows the method of managing data using the conventional CAD system;

FIG. 2 shows the principle of the CAD system;

FIGS. 3A and 3B show the configuration of the data for each of the design planes in the CAD system;

FIG. 4 shows the spatial attribute of the two-dimensional design plane;

FIG. 5 shows the reference relation between design planes;

FIG. 6 shows an image of the process flow of automatically generating a three-dimensional reference;

FIG. 7 is a flowchart of the process flow of automatically generating a three-dimensional reference;

FIGS. 8A and 8B shows the process of converting an placement point and an placement vector;

FIG. 9 is a flowchart of the process of generating a three-dimensional reference and a three-dimensional model;

FIG. 10 shows the process of moving a part on a two-dimensional design plane.

FIG. 11 is a flowchart of the process flow when the part shown in FIG. 10 is moved;

FIG. 12 shows another model reflecting an edit instruction;

5 FIG. 13 shows a case in which an editing operation is performed with a model specified as a target input without switching a work plane or a work space;

FIG. 14 shows the process of generating a new model;

10 FIG. 15 shows the process of inheriting a spatial attribute in each of the two-dimensional design planes in a new model generating process;

FIG. 16 shows an example of a guide;

15 FIG. 17 shows the process of automatically setting a reference point of a specified element in each of the two-dimensional design planes by setting a three-dimensional reference to a three-dimensional design space;

FIG. 18 shows the premise on which a new inter-model reference is set;

20 FIG. 19 shows the process flow of the CASE 1;

FIG. 20 shows the process flow of the CASE 2;

FIG. 21 shows the process flow of the CASE 3;

25 FIG. 22 shows the outline of the configuration of a two-dimensional/three-dimensional cooperative CAD system;

FIG. 23 shows the configuration of the data stored in a model graphics storage database 12;

FIG. 24 shows an example of a configuration of the work plane data unit;

5 FIG. 25 shows an example of a configuration of the work space data unit;

FIG. 26 shows an example of arranging a reference image on a two-dimensional design plane according to the 2D reference information of the work plane data 10 unit;

FIG. 27 shows an example of arranging a reference image on a three-dimensional design space according to the 3D reference information of the work plane data unit;

15 FIG. 28 shows an example of a coordinate correspondence table;

FIGS. 29A, 29B, 29C, and 29D show the correspondence between each of the two-dimensional design planes and its three-dimensional coordinate 20 system;

FIGS. 30A and 30B show the design plane conversion pattern of a 2D3D placement consistency correspondence table using a plane ID;

25 FIG. 31 shows the design plane conversion pattern of a 2D3D placement consistency correspondence table

using the name of a plane;

FIG. 32 shows the design plane conversion pattern of a 2D3D placement consistency correspondence table using the appearance of a three-dimensional coordinate axis;

FIG. 33 shows a 2D3D placement consistency correspondence table indicates by the number of revolutions of the first axis;

FIG. 34 shows a three-dimensional conversion matrix table corresponding to a two-dimensional design plane pattern;

FIG. 35 shows an example of the configuration of an assembly management table;

FIG. 36 shows an example of the configuration of a parentage process table;

FIG. 37 shows an example of the configuration of an terminal model table;

FIG. 38 shows an example of the configuration of a 2D3D parts structure correspondence table;

FIG. 39 shows an example of a prior parent holding table;

FIG. 40 shows an example of spatial placement information temp data;

FIG. 41 shows an example of a parallel plane management table;

FIG. 42 is a flowchart of the flow of a three-dimensional automatic assembly process using a table and data;

5 FIG. 43 is a flowchart (1) of the controllability check process between 2D parts structure work planes and the three-dimensional data converting process of a two-dimensional reference;

10 FIG. 44 is a flowchart (2) of the controllability check process between 2D parts structure work planes and the three-dimensional data converting process of a two-dimensional reference;

15 FIG. 45 is a flowchart of the three-dimensional parts placement information setting process;

FIGS. 46A and 46B show interlocking operations using 6 views;

FIGS. 47 shows the environment of the information process system according to the present system; and

FIG. 48 shows an example of a storage medium.

20 **Description of the Preferred Embodiments**

FIG. 2 shows the CAD system according to an embodiment of the present invention.

21 The present embodiment is based on a CAD system for processing a two-dimensional design plane/three-dimensional design space configured by

referring to a two-dimensional design plane/three-dimensional design space 26.

5 The CAD system 21 comprises an inter-model reference management unit 22 and an intra-model correspondence management unit 23.

23 The intra-model correspondence management unit 25 manages a correspondence 27 between the two-dimensional design plane 25 and the three-dimensional design space 26 for the same target.

10 The inter-model reference management unit 22 manages reference information 28 between models 24 configured by the two-dimensional design plane and the three-dimensional design space for the same target.

15 In this specification, a model is a unit and refers to all design planes (two-dimensional design plane/three-dimensional design space) for the same target such as a part, a unit, etc. Furthermore, a two-dimensional reference refers to a hierarchical reference between two-dimensional design planes to 20 another model, a three-dimensional reference refers to a reference between three-dimensional design spaces, and an inter-model reference refers to a two-dimensional reference and a three-dimensional reference between models. A work plane/space refers 25 to the design plane/space of a model to be processed

in a designing operation.

When one of the two-dimensional reference or the three-dimensional reference between the models 24 is operated, the inter-model reference management unit 5 22 operates another two-dimensional reference and three-dimensional reference between the models corresponding to the above mentioned operation. Thus, the operation in a two-dimensional design plane/three-dimensional design space or the operation in a model 10 can be interlocked with another two-dimensional design plane/three-dimensional design space or another model.

The CAD system 21 can further comprise an automatic assembly unit. The automatic assembly unit generates a three-dimensional reference between the three-dimensional design space 26 of the first model and the three-dimensional design space 26 of the second model from the two-dimensional reference of a plurality of two-dimensional design planes 25 belonging to the first model to the two-dimensional design plane 25 belonging to the second model, and the correspondence 27 of the first model and the correspondence 27 in the second model. The automatic assembly unit automatically assembles the correspondence 27 belonging to the same model 24 using the two-dimensional reference of a plurality of two-

dimensional design planes 25 belonging to the same model 24 and the correspondence 27 in the model 24. Using the automatic assembly unit, the three-dimensional design space 26 having the correspondence 5 27 in a model and the reference information 28 to another model.

The present invention not only includes a CAD system, but also a cooperative system for performing a cooperative process on graphic data between the two-dimensional CAD and the three-dimensional CAD, a CAD 10 data managing method, and a program storage medium.

According to the CAD system of the present embodiment, a three-dimensional reference with another model can be automatically set. Therefore, a three-dimensional design space having a plurality of elements can be automatically assembled. The three-dimensional design space has the correspondence with a two-dimensional design plane in the same model and a three-dimensional reference with another model. 15 Therefore, an operation in a two-dimensional design plane/three-dimensional design space can be reflected in another two-dimensional design plane/three-dimensional design space in a model or in another model.

20 FIG. 3 shows the configuration of the data for

each model in a CAD system according to the present embodiment.

5 In the CAD system, the data of each model comprises the model information shown in FIG. 3A and the model reference information shown in FIG. 3B.

10 The model information stores the information about a two-dimensional design plane and a three-dimensional design space of the model, and the spatial attribute indicating what attribute each two-dimensional design plane has in a three-dimensional design space. In the case shown in FIG. 3, the model A has A1, A2, ... as a two-dimensional design plane, and has AS as a three-dimensional design space. As a spatial attribute, the design plane A1 indicates an 15 XZ plane ($Y = 0$) and the design plane A2 indicates an XY plane ($Z = 0$), in the three-dimensional design space.

FIG. 4 shows a spatial attribute in each two-dimensional design plane.

20 The method of assigning a spatial attribute in the three-dimensional design space of each two-dimensional design plane can be a method of assigning a spatial name in advance such as an 'XY plane', a 'front view', etc., shown in FIG. 3, to fixed views 25 of (1), (2), etc., shown in FIG. 4 for prescription

5 by name, a method of assigning it by a mathematical and direct representation using a normal vector such as $x = 0$, etc., a method of associating an origin in the two-dimensional design plane with an origin in the three-dimensional design space, etc.

10 The model reference information shown in FIG. 3B stores what design plane in another model each design plane/space in a model refers to. For example, in FIG. 3B, for the design plane A1 of a model A, the reference of the design plane B1 of a model B and the reference of the design plane C1 of a model C, and a conversion matrix between an placement vector in the referred-from design plane and a reference vector in the referred-to design plane are stored as reference 15 data.

FIG. 5 shows an example of a reference between a design plane and a space according to the present embodiment.

20 According to the present embodiment, when a model for use in automatically assembling a three-dimensional model is specified, a three-dimensional reference is generated and a three-dimensional model is generated in a three-dimensional work plane from the two-dimensional reference and spatial attribute 25 in the two-dimensional design plane for a part and a

unit to be processed in a designing operation as a preprocess before starting an editing process by a user. Then, a reference between design planes is set for managing information about spatial consistency, 5 etc. from the two-dimensional reference and the three-dimensional reference. Design planes of all related models B through E are referenced from the two-dimensional reference of the two-dimensional design planes A1 and A2 of the model A to be processed in the 10 designing operation shown in FIG. 5. Then, using the two-dimensional reference and the spatial attribute sequentially from the lowest order model, a three-dimensional model is automatically generated in the three-dimensional design space AS while generating a 15 three-dimensional reference.

FIG. 6 shows an image of the process flow for automatically generating a three-dimensional reference.

In FIG. 6, the models B and C are configured 20 without referring to other models at the lowest model. The model A is configured by the models B and C. Since the three-dimensional reference with the model C is generated as in the case of the model B, the explanation is omitted here.

25 The process flow shown in FIG. 6 is described

below by referring to the flowchart shown in FIG. 7.

The following process is performed on each model in order from the model at the lowest hierarchical level.

5 Step I: Determining placement vector

First, the placement point and the placement vector ((5), (6)) for reference placement of the two-dimensional design planes B1 and B2 of the model B with the two-dimensional design planes A1 and A2 of 10 the model A are converted into the point and vector ((7)) in the three-dimensional design space AS using the two-dimensional references ((1), (2)) of the two-dimensional design planes A1 and A2 to the two-dimensional design planes B1 and B2 of the model B, 15 and the spatial attributes ((3), (4)) with the design plane AS.

FIG. 8 shows the process of converting the placement point and the placement vector. FIG. 8 shows the process of converting the points Pa1 (x_1, z_1) and Pa2 (x_2, y_2) and the placement vectors (l_{x1}, l_{z1}) and (l_{x2}, l_{y2}) referring to each of the two-dimensional design planes of the model B on the design planes A1 and A2 into the point and vector in the AS using the spatial attribute with the design plane AS. 20 FIG. 8 shows only the portion corresponding to the 25

model B.

As shown in FIG. 8A, the spatial attributes of the two-dimensional design planes A1 and A2 for the three-dimensional design space AS are such that the 5 two-dimensional plane A1 is the XZ plane ($y = 0$) of the three-dimensional design space AS, and the two-dimensional plane A2 is the XY plane ($z = 0$). Using the spatial attribute, the corresponding point and vector in the three-dimensional design space AS are 10 obtained as shown in FIG. 8B.

When the two-dimensional design plane refers to the design plane of another model, the placement point and placement vector for placement are set at the reference source to determine where in the design 15 plane of the reference source the graphics of the reference destination are to be placed. At the reference destination, the reference point and the reference vector, which are references for use in determining the position and direction of data at the reference source, are set. In the case shown in FIG. 20 6, the placement points Pa1 and Pa2 indicating the positions of the data of the two-dimensional design planes B1 and B2 are set in the two-dimensional design planes A1 and A2 as shown in FIG. 8. To simplify the 25 explanation in the example shown in FIG. 8A, the

design planes A1 and A2 are perpendicular to each other. However, in the following processes, they can be freely set by considering the inclination as an element for a two-dimensional design space in which 5 they are not orthogonal to each other.

As shown in FIGS. 8A and 8B, the placement point Pas of model B in the three-dimensional design space AS is calculated as an intersection X between a line L1 passing the placement point Pal in the A1 plane and 10 perpendicular to the A1 plane ($y = 0$), and a line L2 passing the placement point Pa2 in the A2 plane ($z = 0$) and perpendicular to the A2 plane.

Thus, the placement position Pas is determined in the AS of the three-dimensional model BS.

If the intersection X cannot be obtained and the placement position Pas is not obtained, the three-dimensional inconsistency exists between the design planes A1 and A2, which is notified to the designer to change the position Pal on the two-dimensional 15 design plane A1 or the Pa2 on the two-dimensional design plane A2 into the consistent position. Otherwise, the designer is requested to set the placement position Pas of the model B in the three-dimensional design space.

20 Step II: Determining reference vector

Then, for the model B, the reference point and the reference vector ((10), (11)) on the two-dimensional design planes B1 and B2 of the model B referenced by the two-dimensional design planes A1 and 5 A2 of the model A are converted into the reference position and the reference vector ((12)) in the three-dimensional design space BS, using the spatial attribute ((8),(9)) between two-dimensional design planes B1 and B2 and three-dimensional design space 10 BS.

The converting process performs the process in step I similar to the process performed on the design planes A1, A2, and AS of the model A as shown in FIG. 7B with the placement vector on the design plane A1 15 replaced with the reference vector on the design plane B1, with the placement vector on the design plane A2 replaced with the reference vector on the design plane B2, with the placement vector on the design plane AS replaced with the reference vector on the design plane 20 BS, with the attribute on the design plane A1 replaced with the spatial attribute on the design plane B1, and with the spatial attribute on the design plane A2 replaced with the spatial attribute on the design plane B2. An intersection between a line passing the 25 placement point Pb1 in the B1 plane ($y = 0$) and

perpendicular to the B1 plane, and a line passing the placement point Pb2 in the B2 plane ($z = 0$) and perpendicular to the B2 plane. The point is defined as the placement position Pbs of the model B in the 5 three-dimensional design space BS.

Thus, the correspondence among the reference vector in the model B, a two-dimensional plane, and a three-dimensional space is obtained.

10 Step III: Generating three-dimensional reference data between design planes AS and BS

A conversion matrix M between the placement vector in the three-dimensional design space AS obtained in step I and the reference vector in the three-dimensional design space obtained in step II is 15 generated, and is stored as the three-dimensional reference data from the three-dimensional design space AS to the three-dimensional design space BS.

Step IV: Automatic assembly

Based on the conversion matrix M generated in 20 step III, the three-dimensional data of the model B referenced in the three-dimensional design space AS is copied or referenced, thereby assembling the three-dimensional model.

25 FIG. 9 is a flowchart of the process of the three-dimensional reference, and the three-dimensional

model generation.

First, in step S1, the designer specifies to input a model to be processed. Then, in step S2, the model information and the model reference information 5 of the target model are read from the database, a referenced model is obtained from the model reference information, and the model information and the model reference information about the model are read. The process is performed to the model in the lowest 10 hierarchical level in the reference relation, and the model information and the model reference information about all models directly or indirectly related to the model to be processed in reference are read.

Then, in step S3, the number N of all models is 15 checked from the model information and the model reference information read in step S2, and a list indicating the reference of each model is generated.

Then, the pointer i indicating the process target is initialized to '1', in order from the model in the 20 lowest hierarchical level in the reference correspondence based on the list generated in step S3, the processes in the above mentioned steps I through VI, that is, the placement vector is determined (step S5), a reference vector is determined (step S6), and 25 the three-dimensional reference data is generated

(step S7), and the three-dimensional model is automatically assembled (step S8).

Then, the processes in steps S5 through S8 are performed on all models. When the pointer i reaches 5 the number N of all models (NO in step S9), the process terminates. When the pointer i is smaller than the number N of all models (YES in step S9), the pointer i is incremented by 1 (step S10), and then the processes in steps S5 through S8 are performed on the 10 next model.

In the above mentioned processes, a three-dimensional model can be automatically assembled from 15 a set of two-dimensional figures and unit figures by using the spatial attribute of a two-dimensional design plane and a two-dimensional reference, which cannot be realized by the conventional technology.

In addition, a three-dimensional model in the three-dimensional design space assembled in the above mentioned process has the three-dimensional reference 20 data with a lower order model and a spatial attribute with the two-dimensional design plane in the same model. In each of the two-dimensional design planes in the same model as the three-dimensional model, there is correspondence through a three-dimensional 25 design space. Therefore, the three-dimensional model

can automatically reflect the edited contents on another work plane, or the two-dimensional design plane and the three-dimensional design space can automatically reflect the process on the three-dimensional model. Then, all other related design planes/spaces reflect the edited contents, and consistent new models can be automatically generated, thereby realizing the functions which cannot be realized by the conventional technology by having the correspondence among the two-dimensional design planes/three-dimensional design spaces in the model and the inter-model references as data.

Described below is the part moving process as an example of reflecting an editing process on another design plane/space in the model and on another model.

FIG. 10 shows a moving process.

In FIG. 10, when the position of a part 81 referencing the two-dimensional design plane B1 of the model B is moved on the two-dimensional design plane A1, the moving information M1 indicating the amount and direction of the movement is converted into the moving information M2 in the two-dimensional design plane A2 and the moving information Ms in the three-dimensional design space AS, and the same parts 82 and 83 corresponding in the two-dimensional design plane

A2 and the three-dimensional design space AS move corresponding to the movement on the two-dimensional design plane A1.

FIG. 11 is a flowchart of the process flow in the 5 movement of the parts shown in FIG. 10. In the work plane A1 of the model A, when the designer moves the part 81 on the screen using a move command, it is input as a move instruction (step S21).

According to the move instruction, the moving 10 information M1 is converted into the moving information Ms in the three-dimensional design space AS of the model A using the coordinate correspondence table described later, and the spatial attribute of the two-dimensional design plane A1 (step S22).
15 According to the moving information Ms, the position Pas-2 of the placement vector after moving the part 83 is obtained by converting the position Pas-1 of the placement vector of the model B before the movement, and the three-dimensional model of the model B is placed at the position Pas-2. Thus, the part 83 is 20 moved in the three-dimensional design space AS (step S23).

In the two-dimensional design plane A2, the 25 moving information Ms in the three-dimensional design space AS obtained in step S22 is converted to obtain

the moving information M2 in the two-dimensional design plane A2 (step S24). According to the moving information M2, the position Pa2-2 of the placement vector after moving the part 82 is obtained by 5 converting the position Pa2-1 of the placement vector before moving the model B, and the part 82 referencing the design plane B2 is moved to the position Pa2-2 (step S25). The moving information M2 can be derived in step S24 not according to the moving information 10 Ms, but directly according to the spatial correspondence between the two-dimensional design planes A1 and A2. For example, when the plane A1 is an xy plane, and the design plane A2 is an Xz plane, only the displacement of the moving information M1 in 15 the x direction can be obtained as the moving information M2.

Thus, an edit instruction of figures from the designer in one work plane is automatically reflected on another two-dimensional design plane in the same 20 model or the three-dimensional design space. The reflection of the edit instruction on another two-dimensional design plane and the three-dimensional design space is not automatically performed, but the designer can be notified of whether or not the 25 reflection is performed in an interactive mode.

Otherwise, it can be checked whether or not the edit instruction is consistent, and the reflection can be realized while the check result is notified to the designer.

5 In the above mentioned example, a part is moved,
and another edit instruction without spatial
displacement, for example, copy, delete, shape-change,
color-change, switch display/non-display instructions,
etc. can be performed in the similar converting
10 process using a corresponding reference, thereby the
process contents on one work plane can be inflected
on other two-dimensional design plane and three-
dimensional design space. For example, when a copy
is made, the process is performed to generate an
15 inter-model reference to a new copied model by using
the moving information M_s and M_2 obtained in steps S22
and S24 shown in FIG. 11 as the moving information
from the copy source to the copy destination; not as
the movement in steps S23 and S25 (that is, without
20 deleting the image at the original position).

In addition, the reflection of an edit instruction on another two-dimensional design plane/three-dimensional space in the process using the relation information between each design plane and space can also be reflected on the design plane/design

space of another related model as shown in FIG. 12, not only on the same model as described by referring to FIGS. 10 and 11.

5 In FIG. 12, when the ES is moved to the Ma in the three-dimensional design space AS, the two-dimensional design planes A1 and A2 in the same model are not only changed as interlocking, but a model B is retrieved through the inter-model reference when the three-dimensional design space ES refers to the model B, and
10 there is the model B relating to the moved portion, and a moving process is performed corresponding to the inter-model interlocking on the two-dimensional design plane (B1, B2) and the three-dimensional design space (BS).

15 Thus, the edited contents in one two-dimensional design plane/three-dimensional design space can be interlocked with another two-dimensional design plane/three-dimensional design space because the correspondence is set between the two-dimensional
20 design planes/three-dimensional design spaces in a model and references between models are generated in advance as shown in FIG. 5.

Since the correspondence for the two-dimensional design planes and the three-dimensional design spaces
25 in the same model and an inter-model reference are

managed, a portion where a target input has conventionally been switched does not require a work plane to be processed or a work space to be switched in performing an editing operation.

5 FIG. 13 shows an example of an editing operation. Since data cannot be conventionally referenced over a design plane and a space, only one design plane/design space can be specified as a target input. For example, as shown in FIG. 13, when a change (a) 10 is made from the two-dimensional design plane A1 to the model C, when a change (b) is made from the two-dimensional design plane A2, and when an edition (c) is added from the three-dimensional design space AS, the process (b) is performed after the work plane is 15 switched into the two-dimensional design plane A2 after performing the process (a) after switching the work plane into the two-dimensional design plane A1, and then the process (c) has to be performed after switching the target work into the three-dimensional 20 design space AS. Thus, the work plain/space is sequentially switched to perform an editing process. This is a troublesome work in designing a machine whose design is frequently changed and in setting 25 designing steps.

However, in the system according to the present

embodiment, since reference data and graphic data can be referenced over models and over a two-dimensional design plane and a three-dimensional design space in a model, the model C can be specified as a target 5 input in FIG. 13, and processes (a), (b), and (c) can be input without switching the work plane/work space in the model A which is a higher order model to the model C, thereby storing the result can be stored in the corresponding work plane/work space C1, C2, and 10 Cs as the processes (A), (B), and (C).

By containing data for correspondence in a model and for reference between models, a specific element can be selected from a work plane/space, and a lower order model containing the element can be newly 15 generated.

FIG. 14 shows the process of generating the new model.

FIG. 14 shows an example of generating a new model Z from the model B shown in FIG. 5.

20 First, the designer specifies an element for a new model from any of the two-dimensional design planes B1, B2, and the three-dimensional design space BS of the model B. In the case shown in FIG. 14, an element is specified from the three-dimensional design 25 space BS. At this time, without specifying an element

on other work planes B1 and B2 by switching the three-dimensional work space, an element corresponding to the element specified from the three-dimensional design space BS based on the correspondence between 5 the two-dimensional design plane/three-dimensional design space can be automatically selected on the two-dimensional design planes B1 and B2.

When the specified element is moved to a new model Z, the inter-model reference between the models 10 B and Z can be automatically generated based on the correspondence in a model of the model B and the inter-model reference with another model.

FIG. 15 shows the process of inheriting a spatial attribute in each of the two-dimensional design planes 15 in the process of generating a new model as shown in FIG. 14.

When a new model is generated, each of the two-dimensional design planes of the new model can maintain the consistency in three dimensions by 20 inheriting the spatial attribute of the two-dimensional design plane from the original model. In the case shown in FIG. 15, when the two-dimensional design plane Z1 is generated, it inherits the spatial attribute 'plan view' from the corresponding two-dimensional design plane of the model B which is the 25

original model, and the two-dimensional design plane Z2 inherits the spatial attribute 'front view'. If the designer issues an instruction to rotate the coordinate axis or perform a mirror conversion when a new model is generated, a corresponding spatial attribute should be obtained through conversion. For example, if the designer issues an instruction to rotate the Z axis by 90 degrees as shown in FIG. 15, the spatial attribute of the two-dimensional design plane Z1 is converted from the 'plan view' of the two-dimensional design plane B1 to the 'front view'. In addition, when the three-dimensional design space ZS is generated, a spatial attribute is inherited from the three-dimensional design space BS of the original model B. As in the case of the two-dimensional design plane, a conversion is performed into the corresponding spatial attribute in the three-dimensional design space at the instruction to rotate the coordinate axis or perform a mirror conversion.

20 Described below is the process performed when a
specified element is moved to a new model shown in
FIG. 14. When a specified element is moved from the
original model to a new model by specifying it from
the two-dimensional design plane of the specified-from
25 model, the designer has to set a reference point for

the specified element. According to the system of the present embodiment, the designer is guided to (automatically) maintain the spatial consistency of the new model when the reference point is specified.

5 FIG. 16 shows an example of the guide of the system. In the example shown in FIG. 16, the three two-dimensional design planes X1 (xz plane), X2 (xy plane), and X3 (zy plane) of the original model X, the designer specifies a reference point in the order of
10 X1, X2, and X3.

First, the designer specifies an element 141 to be moved to a new model on the two-dimensional design plane X1, and specifies (1) as a reference point of the element 141.

15 Then, the designer specifies an element 142 to be moved to a new model to set a reference point on the two-dimensional design plane X2. When a reference point (2) is to be set for the element 142, the system recognizes that (a) on the two-dimensional design plane X1 is the same as (c) on the two-dimensional design plane X2 from the position of the reference point 1 of the two-dimensional design plane and the reference between the two-dimensional design planes X1 and X2, fixes the x direction as an input guide on
20 the two-dimensional design plane X2, and defines the
25

specification only in the y direction.

When the designer sets the reference point (2) on the two-dimensional design plane X, the system recognizes that (e) on the two-dimensional design 5 plane X3 is the same as (d) on the X2, and (f) on the X3, is the same as (b) on the X1 from the setting positions of the references (1) and (2) and the reference among the two-dimensional design planes X3, X1, and X2. Thus, the reference point (3) consistent 10 with the reference points (1) and (2) is automatically set for the element 143 on the two-dimensional design plane X3.

A spatially consistent reference point can be set 15 by the guide of the system as a reference point on the two-dimensional design plane.

Since the reference between the three-dimensional design space and each of the two-dimensional design planes is set and managed in the present system, the reference point of a specified element on each of the 20 two-dimensional design planes is automatically obtained by setting a three-dimensional reference on the three-dimensional design space.

In FIG. 17, when the reference point (1), the first axis (x axis), and the second axis (y axis) are 25 set in the three-dimensional design space Xs, the

reference point for the two-dimensional specified element selected on each of the two-dimensional design planes X1, X2, and X3, and the placement angle among the first axis (2) and (3), the second axis (4), and the first axis of the new model are automatically obtained as a two-dimensional reference.

Described below is the settings of inter-model references of new models.

The following explanation describes an example 10 in which the model C is referenced and placed for the model A shown in FIG. 18.

CASE 1 (when a model is set and placed on one two-dimensional design plane (front view))

FIG. 19 shows a process flow in which a two-dimensional design plane C2 is set and placed on one two-dimensional design plane A2 (front view) as CASE 15 1.

First, the designer specifies a referenced-from 20 design plane A2 and a referenced-to design plane C2 (step S31).

Then, the designer specifies a reference point for reference and placement on the referenced-to 25 design plane C2, a reference vector indicating a direction, and a placement vector indicating a placement position and direction on the design plane

C2 of the referenced-from A2 (step S32).

The design plane C2 is set and placed on the design plane A2 by aligning the reference vector at the referenced-to plane set in step S32, on the placement vector at the referenced-from plane

5 . Thus, the reference between the design plane A2 and the design plane C2 is generated (step S33).

CASE 2

10 FIG. 20 shows a case as CASE 2 in which a reference is set between design planes of the same model after setting the reference for one two-dimensional design plane in CASE 1.

15 As an initial state shown in FIG. 20, a reference is set between the design plane A2 which is a front view of the model A and the design plane C2 of the model C. From the state, a reference is set between the two-dimensional design planes A1 and C1 which are the plan views of the models A and C respectively from the two-dimensional references of the design planes 20 A2 and C2, the coordinate correspondence table, and the 2D3D placement consistency correspondence table described later.

25 First, the designer specifies a specified element 181 on the design plane C1 (step 41). Then, the system displays as a guide a straight line 182

corresponding to the reference point of the design plane C2 using the coordinate correspondence table described later. And the designer sets the reference point (1) to maintain consistency with the straight line 182 (step 42).

Then, the system displays a guide line 183 fixed in the axis direction on the two-dimensional design plane A1 to maintain the consistency between the reference point 1 and the design planes A2 and C2.

10 The designer sets the placement point (2) at any position on the guide line (step 43). A 7oreference (two-dimensional reference) can be set between the two-dimensional design planes A1 and C1 by setting and placing the design plane C2 on the two-dimensional design plane A1 with the placement point (2) aligned on the reference point (1) on the design plane C1. Two two-dimensional references, which are between the design plain A1 and C1 and which are between the design plains A2 and C2, are set between the model A and C.

15 Thus, a view interlocked 2D parts structure data is generated, and a part can be recognized over a plurality of views, thereby realizing an interlocking operation.

20 CASE 3 (setting two-dimensional reference after
setting three-dimensional reference)

FIG. 21 shows a case as CASE 3 in which a three-dimensional reference is set between three-dimensional design spaces, and a two-dimensional reference is set based on the three-dimensional reference.

5 In FIG. 21, when the designer selects a specified element 191 in the three-dimensional design space CS of the model C, the system indicates to the designer the referent point, the first and second axes (reference vector (1)) for the specified element 191
10 (step 51).

Then, the system indicates the placement point, the first axis, and the second axis (placement vector (2)) in the three-dimensional design space AS of the model A where they are placed (step 52). A reference
15 (three-dimensional reference) is set between the three-dimensional design spaces AS and CS by the designer setting and placing the three-dimensional design space CS in the three-dimensional design space AS with the reference vector (1) in the three-dimensional design space CS aligned on the placement vector (2) (step 53).

20 Then, the designer selects and indicates specified elements 192 and 193 from the model A and the two-dimensional design planes C1 and C2 of the model C in which a three-dimensional reference is set
25

(step 54). Thus, a two-dimensional reference is automatically generated from the three-dimensional reference set in step S53, the coordinate correspondence table, and the 2D3D placement consistency correspondence table described later (step S55).

The processing operations according to the present embodiment described above are explained below by referring to a practical configuration.

10 In the following descriptions, each of the two-dimensional design planes includes only six views. One model is placed on the parent model only one placement. The operation such as moving a part, etc. is only a parallel movement and a rotating movement
15 in 90° unit.

The assumption above is given for simple explanation, and can be easily extended using the data structure and process described below.

- 20 · Data is extended with a plane defined as an optional plane in a space.
- A two-dimensional design plane - three-dimensional design space correspondence table is generated based on the extended data.
- When an optional moving operation is performed,
25 it is necessary to change or newly set a two-

dimensional reference, but the processes for them are performed with the moving operation or in an interactive mode. In addition, a consistency check is made and the check result is notified.

5 · A two-dimensional data is newly set from three-dimensional data for an unplaced work plane or non-existing work plane. Otherwise, a new corresponding work plane is set, and a process is performed for generating the shape, etc.

10 FIG. 22 shows the outline of the configuration of the present invention when it is configured as a two-dimensional/three-dimensional cooperative CAD system. The present invention is not only realized as a two-dimensional/three-dimensional cooperative CAD
15 15 as shown in FIG. 22, but can be configured as a two-dimensional CAD or a three-dimensional CAD. In this case, the two-dimensional/three-dimensional CAD according to the present embodiment is connected to a three-dimensional CAD or a two-dimensional CAD with a different configuration, and these CAD systems
20 20 comprises cooperation units which share two-dimensional/three-dimensional data, and cooperate the plurality of CAD systems. Otherwise, it can be configured as a cooperative system for realizing the
25 25 cooperation between a two-dimensional CAD and a three-

dimensional CAD.

A two-dimensional/three-dimensional cooperative CAD system 1 shown in FIG. 22 is connected to a user input/output unit 2 for communicating with the 5 designer for operating and designing a system. The user input/output unit 2 can be, for example, a terminal information processing device, a monitor, a printer, a keyboard, a pointing device, etc. with which the designer specifies and inputs to the two-dimensional/three-dimensional cooperative CAD system 10 1, or the two-dimensional/three-dimensional cooperative CAD system 1 outputs to the designer two-dimensional/three-dimensional data such as a two-dimensional figure, a three-dimensional model, etc. 15 The two-dimensional/three-dimensional cooperative CAD system 1 comprises a two-dimensional/three-dimensional data edition unit 11, the model graphics storage database 12, a table file 13, and work memory 14. FIG. 22 shows only the portion relating to the 20 present embodiment.

The two-dimensional/three-dimensional data edition unit 11 is a unit for processing the two-dimensional/three-dimensional data processed by the two-dimensional/three-dimensional cooperative CAD 25 system 1, generates a work plane on the user

input/output unit 2 from the data in the model graphics storage database 12, receives an operation instruction from the designer, performs a corresponding process, etc. In addition, at an 5 instruction from a user, it automatically assembles a three-dimensional model in a three-dimensional design space from the two-dimensional/three-dimensional data in the model graphics storage database 12 using each table in the table file 13, 10 generates various tables described later on work memory, sets and manages an inter-model reference and the correspondence in a model, etc. The two-dimensional/three-dimensional data edition unit 11 can also be realized by hardware, but generally realized 15 by software.

The model graphics storage database 12 stores the data of each design plane as a database for each model. The table file 13 stores a processing table used by the two-dimensional/three-dimensional data edition unit 11. The work memory 14 is used by the 20 two-dimensional/three-dimensional data edition unit 11 as a work memory in the process. The work memory 14 stores the correspondence between a two-dimensional design plane and a three-dimensional design space in 25 the model and a reference between models in the form

of a table.

FIG. 23 shows the data structure of the model graphics storage database 12. The model graphics storage database 12 stores the data of each design 5 plane as a database for each model, and contains a model information unit 122 corresponding to the model information shown in FIG. 3A, a work plane data unit 123 corresponding to each of the two-dimensional design plane, and a work space data unit 124 corresponding to the three-dimensional design space 10 as a database for each model.

The model information unit 122 is generated for each model, and manages the data of the two-dimensional design plane/three-dimensional design 15 space of the model. The model information unit 122 comprises the number of two-dimensional design planes, the design plane ID of the two-dimensional design plane, and a design space establishment flag indicating whether or not the model has a three-dimensional design space.

The work plane data unit 123 manages the information about a two-dimensional design plane in each model. The work space data unit 124 manages the information about a three-dimensional design space in 20 each model.

FIG. 24 shows an example of the configuration of the work plane data unit 123

The work plane data unit 123 is a graphic storage area storing two-dimensional data in each model, and 5 comprises a plane name, a plane ID, a graphic data unit, and a single 2D part structure data unit.

A plane name refers to the name of a design plane corresponding to the work plane data unit 123. A plane ID refers to an identifier of the design plane, and corresponds to the design plane ID in the model information unit.

The graphics data unit and the single 2D parts structure data unit stores graphics data of a figure of a two-dimensional design plane. The graphics data unit stored the data newly added on the screen, and is configured by graphics information such as a graphics ID, the type and size of graphics, etc. The single 2D parts structure data unit stores the information for the two-dimensional design plane of another model referenced by the two-dimensional design plane to process a referenced design plane as a process unit. When the design plane references another design plane, the file name indicating the model to which the design plane belongs, the plane data unit name for identification of the design plane

in the file, the placement point and placement angle indicating the placement position, a mirror flag indicating whether or not a mirror conversion is performed, and when a mirror conversion is performed, 5 an ID assigned to each design plane referenced by the mirror axis as 2D reference information are stored. When the design plane is in the lowest hierarchical level in the reference and does not reference other design planes, the work plane data unit 123 does not 10 have the single 2D parts structure data unit.

FIG. 25 shows an example of the configuration of the work space data unit 124.

15 The work space data unit 124 has basically the same configuration as the work plane data unit 123 shown in FIG. 24, and is a graphics storage area for storing three-dimensional data in each model. The work space data unit 124 comprises a graphics data unit and a single 3D parts structure data unit.

20 The graphics data unit and the single 3D parts structure data unit correspond to the graphics data unit and the single 2D parts structure data unit shown in FIG. 25, and stores the graphics data of a figure in a three-dimensional design space. The single 3D parts structure data unit stores the information for 25 the three-dimensional design space of another model

referenced by the three-dimensional design space, the file name indicating the child model to which a referencing design plane belongs, the placement point indicating the placement position, the first axis 5 which is the coordinate axis of the patent model corresponding to the X axis of the child model, and the second axis which is the coordinate axis of the parent model corresponding to the Y axis of the child model, with the ID assigned for each design plane 10 referred to as the 3D reference information. When the design space is in the lowest hierarchical level in the reference and does not reference other design spaces, the work space data unit 124 does not have the single 3D parts structure data unit as in the work 15 plane data unit 123.

FIG. 26 shows an example of the placement of a reference image to the two-dimensional design plane according to the 2D reference information of the work plane data unit 123.

FIG. 26 shows an example of referencing and placing a two-dimensional design plane of 'XY' of the model of a 'figure 1 of a part' on the view of 'XY' of the model of a 'figure of a unit'. In this example, the x axes of the referenced-from and 20 referenced-to two-dimensional design planes are placed 25

to be parallel (having an angle of 0°) to each other with the reference point (0, 0) of the referenced-to two-dimensional design plane ('XY' of the model 'figure 1 of a part') aligned on the referenced-from 5 placement point (20, 20) corresponding to the placement point and placement angle in the 2D reference infomation of two-dimensional design plain 'XY' of the model 'figure of a unit'. Since the mirror flag is set to 0, the two-dimensional design plane is 10 placed without a mirror conversion.

FIG. 27 shows an example of placing a reference image on a three-dimensional design space according to the 3D reference information of the work space data unit.

15 FIG. 27 shows an example of referencing and placing the three-dimensional design space of a model of a 'figure 1 of a part' on the view of the three-dimensional design space of the model of a figure of a unit. Coordinates are converted such that the 20 referenced-to first axis (x axis) can be the referenced-from -y axis, and the referenced-to second axis (y axis) can be the referenced-from -z axis, and the reference point (0, 0, 0) of the referenced-to three-dimensional design space is aligned to the 25 placement point (15, 10, 10) of the referenced-from

three-dimensional design space aligned, corresponding to the placement point and the placement angle of the 3D reference information of the 'figure of a unit' of the model.

5 Described below is the coordinate correspondence table and the 2D3D placement consistency correspondence table stored in the work memory 14.

FIG. 28 shows the configuration of the coordinate correspondence table.

10 The coordinate correspondence table shows the spatial position of the two-dimensional design plane in the three-dimensional design space.

FIG. 29 shows the correspondence between the two-dimensional design plane and the three-dimensional design space.

15 According to the present embodiment, each of the two-dimensional design planes indicates any of the 6 views, but the 6 views are, as shown in FIG. 29A, based on the three sides of the x, y, and z axes in a three-dimensional space, and are defined as 6 pieces of infinite planes passing the origin. According to the present embodiment, when a three-dimensional space is developed on a two-dimensional design plane, as shown in FIG. 29A, each of the two-dimensional design planes passes the origin of the three-dimensional

space, and is defined as a plane having any of the x, y, and z axes as a normal vector. The plane ID as shown in FIG. 29B and the plane name as shown in FIG. 29C, are assigned for each of these two-dimensional 5 design planes. In addition, each of the two-dimensional design planes is defined as a coordinate system with the right direction defined as the + direction of the first axis (α axis) as shown in FIG. 29D, and with the up direction defined as the + 10 direction of the second axis (β axis).

15 The coordinate correspondence table shown in FIG. 28 shows the spatial position in the three-dimensional design space for each of the two-dimensional design planes shown in FIG. 29C, and comprises for each of the two-dimensional design planes the plane ID, the plane name, the appearance of the three-dimensional coordinate axis from each of the planes, the conversion equation (matrix) from each two-dimensional design plane to the three-dimensional spatial coordinates, a conversion table from the two-dimensional data to the three-dimensional data (from each of the two-dimensional design plane to the three-dimensional coordinates) corresponding to the conversion equation, and a conversion table from three-dimensional data to two-dimensional data (the

three-dimensional coordinates into two-dimensional design planes).

FIG. 30 shows a design plane conversion pattern of the 2D3D placement consistency correspondence table 5 using the plane ID. The 2D3D placement consistency correspondence table is used to check the consistency when the design plane of a referenced child model is set and placed on the design plane of a referenced-from parent model.

10 When a child figure is referenced and placed with three-dimensional consistency with the parent, the placement is limited to a specific method. Therefore, the consistency can be checked by checking how and what child figure is to be referenced and placed to 15 which parent figure.

20 In this embodiment, each of the two-dimensional design planes is any of the six views. Therefore, in the case of consistent reference or placement, the reference between a parent figure and a child figure can be one of the 24 patterns shown in FIG. 30B.

25 That is, if reference or placement is performed with any of the 24 patterns shown in FIG. 30B at the position of the parent figure shown in FIG. 30A, then the reference is consistent. For example, if the two-dimensional design plane of the plane ID1 of the

parent figure references and places the child figure of the two-dimensional design plane of the plane ID 6, and the planes ID 2, 3, 4, 5, and 6 respectively reference and place the planes ID 3, 2, 5, 4, and 1, 5 then it corresponds to the rightmost pattern at the bottom shown in FIG. 30B. In this case, it is determined that the reference is consistent.

FIG. 31 shows the placement pattern of the reference between a parent figure and a child figure 10 shown in FIG. 30 using a plane name, not a plane ID. FIG. 32 shows the placement pattern of a reference shown in FIG. 30 from the appearance of the three-dimensional coordinate axis viewed from each plane. With the 2D3D placement consistency correspondence 15 table configured as shown in FIGS. 31 and 32, the table can be used in checking the consistency of the reference as in the case shown in FIG. 30.

FIG. 33 shows a 2D3D placement consistency correspondence table showing the placement pattern of 20 the reference between a parent figure and a child figure by the number of revolutions of the first axis (α axis) in the placement process. Each position of the child figure shown in FIG. 33 corresponds to FIGS. 31, 32, and 33.

25 In FIG. 33, 0° , $(\pm) 90^\circ$, 180° , and 270° show the

counterclockwise revolution angle for the first axis when placement is performed on the parent figure. In addition, the α mirror and the β mirror indicate the mirror conversion performed on the α axis and the β axis.

A consistency check about the placement of a child figure to a parent figure is made by checking whether or not the same placement pattern exists on FIGS. 33, 31, and 32.

10 FIG. 34 shows a three-dimensional conversion matrix table corresponding to the two-dimensional design plane pattern.

The position of each box shown in FIG. 34 corresponds to the child figure of the 2D3D placement consistency correspondence table shown in FIGS. 30, 31, 32, and 33.

20 FIG. 34 shows matrixes corresponding to the coordinate conversion from a child model to a parent model and a correspondence matrix. For example, the upper right ($x \ y \ z$) \rightarrow ($y \ -x \ z$) indicates that the coordinates of the child model ($x \ y \ z$) is converted into a parent model ($y \ -x$ and z) in the parent model in the matrix operations using a corresponding matrix.

25 14 by the two-dimensional/three-dimensional data

edition unit 11 when the automatic assembling process on the three-dimensional model is started is described below. The process tables are reference data which is used to manage the reference between two-dimensional design planes and a three-dimensional design space, and the inter-model reference, and corresponds to the model reference information shown in FIG. 3B.

On the table generated on the work memory 14 can be an assembly management table, a parentage process table, a terminal model table, a 2D3D placement consistency correspondence table, a prior parent holding table, and a spatial placement information temp data. Among them, the prior parent holding table and the spatial placement information temp data are temporary data temporarily generated in the process.

FIG. 35 shows an example of the configuration of the assembly management table.

An assembly management table is used when an ID (model ID) is assigned to the data of each model forming the hierarchical structure, and manages the correspondence between a model name (file name of the model) and the model ID. In the example shown in FIG. 35, the number of total models is N, and the model ID 1 through N for all models and the corresponding model

names are stored.

The assembly management table is generated by the preprocess of the three-dimensional model automatic assembly process. The assembly management table is 5 generated while the file of the model to be processed in the process model ID assigning process is read from the model graphics storage database 12, and the placement relation is sequentially retrieved from a parent model to a child model.

10 The parentage process table manages the information about the reference (parentage) between a model specified by a user to be processed and another model, and the order in the parentage process.

15 FIG. 36 shows an example of the configuration of the parentage process table.

In the parentage process table, a record is generated for each model which is a parent model to any model. A record in the table comprises a parentage process order ID, a parent model ID, a 20 placed child model ID, the number of placed models, and a terminal process flag. The parentage process order ID is an ID assigned to a model which is a parent model of any model, and indicates the order in the parentage process in which the parentage of models 25 is retrieved and processed. The three-dimensional

model automatic assembly process is performed in the reverse order of the parentage process order ID. The parent model ID is a model ID of a parent model in the reference. The number of placed models and the placed 5 child model ID respectively indicate the number of child models which the parent model refers to and places, and the model ID of the child model. The terminal process flag indicates a flag when the parentage process is no more required, and there are 10 no reference in the lower levels in the structure.

The terminal model table shows the model at the lowest hierarchical level in the reference, and the model ID of the terminal model having no child model is set.

15 FIG. 37 shows an example of the configuration of the terminal model table. In FIG. 37, the number of terminal models and the model IDs are stored together with the serial number of the IDs of the terminal models. By checking the terminal model table, the 20 two-dimensional/three-dimensional data edition unit 11 can recognize that there is no reference at a level lower than the model stored in this table.

25 The 2D3D parts structure correspondence table is generated for the parentage managed on the parentage process table, and manages the information as to which

two-dimensional design plane of a child model is referenced and placed on which two-dimensional design plane of its parent model, how many models are placed, etc., for each parentage. In the parentage, reference 5 and placement is performed among three-dimensional design spaces, and it is managed whether or not a three-dimensional reference is set.

FIG. 38 shows an example of the configuration of the 2D3D parts structure correspondence table.

10 The 2D3D parts structure correspondence table comprises a parentage process ID, a child model ID, a view interlocking 2D parts structure data unit, and a 3D space placement flag. The parentage process ID corresponds to the parent model ID of the parentage 15 process table. The child model ID is any of the placed child ID stored in the record of the parent model ID corresponding to the parentage ID in the parentage process table. The view interlocking 2D parts structure data unit stores data used to recognize two-dimensional data as one part over two-dimensional design planes, and stores the number of placed planes, the parent figure placement plane IDs of the number of placed planes, and the child figure placement plane ID. The 3D space placement flag 20 indicates whether or not a 3D reference is set for the 25

parentage managed by the 2D3D parts structure correspondence table. If 0 is set, the flag indicates that the three-dimensional design space of a child model is not referenced or placed for the parent model, and a three-dimensional reference is not set. If 1 is set, the flag indicates that the three-dimensional design space is referenced and placed for the parent model, and a three-dimensional reference is set between the child model and the parent model.

10 FIG. 39 shows a prior parent holding table. The
prior parent holding table is a temporary table for
a parentage process performed over all hierarchical
levels, and stores a parent model ID (parentage
process ID), the number of child models, a serial
15 number (ID), a child model ID, and a check flag.

FIG. 40 shows the spatial placement information temp data.

The spatial placement information temp data stores 3D data and its three-dimensional placement position coordinate information etc.

FIG. 41 shows a parallel plane management table.

The parallel plane management table stores a set of plane IDs of the planes placed in parallel in a three-dimensional space.

FIG. 43 is a flowchart of the entire flow of the

three-dimensional automatic assembly process using each table and data processed by the two-dimensional/three-dimensional CAD data process unit 11.

5 In FIG. 42, a model ID assigning process is performed in step S101. The model ID assigning process comprises an assembly management table setting process for setting an assembly management table shown in FIG. 35 and a terminal model table setting process 10 for setting a terminal model table shown in FIG. 37. In this model ID assigning process, the model graphics storage database 12 is sequentially searched from the parent model, and an ID is assigned to each model.

15 In step S102, a parentage data extracting process is performed from the 2D parts hierarchical structure. The parentage data extracting process from the 2D parts hierarchical structure comprises a parentage process table setting process for performing a parentage process table setting process shown in FIG. 20 36 and a 2D3D parts structure correspondence table setting process for setting the 2D3D parts structure correspondence table shown in FIG. 38. The parentage process setting table setting process extracts the parentage by retrieving the single 2D parts data unit 25 of all plane data units of each model sequentially

from the model at highest hierarchical level, and sets it in the parentage process table. A terminal process flag is set by matching the placed child model ID with the terminal model table, and setting a terminal process flag when all placed child model IDs exist in the terminal model table. The 2D3D parts structure correspondence table setting process is a process that sets a 2D portion which is the data for recognition of a part over views on the 2D3D parts structure correspondence table. This process is performed by retrieving the parentage and setting a view interlocking 2D parts structure data unit on the 2D3D parts structure correspondence table between all parentage.

In step S103, the three-dimensional placement information extracting process from the 2D parts placement information is performed on all parentage set on the parentage process table and the 2D3D parts structure correspondence table in the reverse order of the order ID of the parentage process table. The three-dimensional placement information extracting process comprises a consistency check process between work planes of the 2D parts structure, a three-dimensional data converting process of the two-dimensional reference, and a three-dimensional parts

placement information (three-dimensional reference data) setting process.

In the same model, there is correspondence between a two-dimensional design plane which is a two-dimensional plane and a three-dimensional design space which is a three-dimensional space according to the coordinate correspondence table. Since the placement information in the two-dimensional plain (two-dimensional reference) is the placement information in a parent model, the two-dimensional reference is converted into three-dimensional information as the spatial placement information (three-dimensional reference) of a parent model in the three-dimensional data. Therefore, the three-dimensional placement information extracting process is performed by the consistency check process between work planes of the 2D parts structure, the three-dimensional data converting process of two-dimensional reference, and the three-dimensional parts placement information (three-dimensional reference data) setting process.

Finally, in step S104, using the 3D reference data obtained in the three-dimensional placement information extracting process from the 2D parts placement information in step S103, the 3D parts automatic assembly process for displaying or copying

the three-dimensional model of a child model to a parent model in the reverse order of the order ID of the parentage process table is performed.

5 FIGS. 43 and 44 are flowcharts of the detailed process flow of the consistency check process between

the 2D parts structure work planes and the converting process form the two-dimensional reference to the three-dimensional data process in step S103 shown in FIG. 42

10 The consistency check process between the 2D parts structure work planes and the converting process form the two-dimensional reference to the three-dimensional data are performed by checking the consistency of the design plane of the child model

15 placed on the design plane of the parent model for the parentage set on the parentage process table and the 2D3D parts structure correspondence table, and, if

there is no inconsistency, storing the coordinate axis, etc. of the parent model corresponding to the

20 y axis of the child model in the work memory 11 as the spatial placement information temp data with the coordinate axis of the parent model corresponding to the x axis of the child model as the first axis.

When the process starts, the spatial placement
25 information temp data is cleared (step S201).

Then, in the current target parentage (parent ID, child ID), the view interlocking 2D parts structure data of the corresponding 2D3D parts structure table corresponding to the current target parentage and the 5 single 2D parts structure data unit of the work plane data unit 123 of each design plane are searched to extract necessary information (step S202). When the number of placed models referenced or placed on the design plane of the parent model is 1 (=1 in step 10 S203), the parent placement plane ID, the child placement plane ID, the reference point, and the placement angle are extracted from the work plane data unit 123 and the 2D3D parts structure table (step S205). Then, the guide passing through the reference 15 point in the direction of the normal vector of the parent placement plane is presented, and the user specifies the depth (step S206).

The data obtained in steps S205 and S206 is converted into three-dimensional data based on the 20 coordinate correspondence table, stored in the spatial placement information temp data (step S207), thereby terminating the three-dimensional data converting process.

In step S203, if the number of new placed parent 25 models on the design plane is two or larger (≥ 2 in

step S203), it is checked whether or not there are non-parallel parent placement planes and child placement planes (step S204). The check is made by matching the parallel plane management table shown in FIG. 41 with the plane ID of a parent placement plane and a child placement plane to check whether or not there is a combination not entered in the parallel plane management table. If there is no non-parallel planes (NO in step S204), then control is passed to the process in step S205. If there is non-parallel planes (YES in step S204), control is passed to the process in step S208.

15 In step S208, the consistency is checked using the view interlocking 2D parts structure data and the two-dimensional reference data. The consistency check is made by computing the intersection between the lines vertical to the plane of the parent model placed through the placement point of each of the two-dimensional references (step S208A), and comparing the 20 two-dimensional reference data with the 2D3D placement consistency correspondence table (step S208B).

Next, it is determined whether or not there is inconsistency (step S209). If yes, that is, if no intersection can be obtained on the three-dimensional space, or there is parentage not entered on the 2D3D

placement consistency correspondence table (YES in step S209), the designer interactively maintains the consistency, and a consistency check is made again in step S208.

5 If it is determined in step S209 that there is no inconsistency (NO in step S209), then the obtained three-dimensional intersection is stored in the 3D placement position of the spatial placement information temp data (step S210).

10 Then, the 2D reference data whose parent placement plane has the smallest ID value is extracted, the 2D3D placement consistency data is checked as to which x, y, and z axes of the parent model match the x, y, and z axes of the child model,
15 the first axis of the spatial placement information temp data stores the coordinate axis of the parent model corresponding to the x axis of the child model, and the second axis stores the coordinate axis of the parent model corresponding to the y axis of the child model (step S211), thereby terminating the process.

FIG. 45 is a flowchart of the details of the three-dimensional parts placement information (three-dimensional data) setting process in step S102 shown in FIG. 42.

When the process shown in FIG. 45 starts, the

spatial placement information temp data obtained in the consistency check process (step S208) between the 2D parts structure work planes and the three-dimensional data converting process (step S207) of the 5 two-dimensional reference, shown in FIGS. 42 and 43, are stored as the 3D reference information in the single 3D parts data unit in the work space data unit 124 of the corresponding parent model (step S301).

Then, a corresponding 3D space placement flag of 10 the 2D3D parts structure correspondence table is set (step S302), thereby terminating the process.

FIG. 46 shows an interlocking operation in 6 views.

FIG. 46 shows the interlocking operations of a 15 child figure moving on a two-dimensional design plane and interlocking on another two-dimensional design plane.

Two-dimensional design planes V1 through V6 are set in each of the six child figures shown in FIG. 20 46A. A through F indicate the vertical axes of each of the two-dimensional design planes V1 through V6.

As shown in FIG. 46A, in each child figure in 25 which the two-dimensional design planes V1 through V6 and their vertical axes A through F are set, if the vertical axes A through F in each of the child figures

are moved in the arrow direction as shown at the leftmost column shown in FIG. 46B, another child figure interlocks the movement and moves in the arrow direction as indicated at the columns of V1 through
5 V6.

FIG. 47 shows the environment of each of the information processing systems of the CAD system, the cooperative system, etc. according to the above mentioned embodiments.

10 As shown in FIG. 47, the information processing system comprises a CPU 201, a main storage device 202, a hard disk device 203, an input/output device 204 provided with a display, a keyboard, a mouse, etc., a network connection device 205 such as a modem, a LAN
15 adapter, etc., a portable storage medium 207 such as a CD, a DVD, an optical disk, a floppy disk, etc., and a medium reading device 206 for reading the stored contents. A bus 208 interconnects these units.

20 In the information processing system shown in FIG. 47, the medium reading device 206 reads the program and data stored in the portable storage medium 207. The read program and data are loaded onto or stored in the main storage device 202 or the hard disk device 203. Each of the processes according to the
25 present embodiments can be realized as the operation

of software by the CPU 201 loading onto the main storage device 202 and executing the program and data.

In the information processing system, application software can be switched using the portable storage medium 207. Therefore, when the present invention is used in a computer, not limited to a CAD system or a CAD cooperative system, it can be realized as a computer-readable storage medium used to direct the computer to perform the functions according to the above mentioned embodiments of the present invention.

In this case, the storage medium can be, as shown in FIG. 48, CD-ROM, a portable storage medium 306 removable from a medium drive device 307 such as a floppy disk (or a MO, a DVD, a removable magnetic disk, etc.), etc., a storage device (database, etc.) 302 in the information processing device (server, etc.) held by an external information provider transmitted through a network circuit 303, memory (RAM or external storage device) 305 in a body 304 or an information processing device 301, etc. A program stored in the portable storage medium 306 and the storage device (database, etc.) 302 is loaded onto the memory (RAM or an external storage device, etc.) 305 in the body 304, and is executed to realize each function of the above mentioned embodiments of the

present invention.

As described above in detail, according to the present invention, a three-dimensional model can be automatically assembled according to the information 5 for management of the hierarchical structure in a two-dimensional design plane/three-dimensional design space.

An editing operation can be performed by moving, 10 copying, deleting, etc. parts over plural views as interlocking operations between two-dimensional design planes or between a two-dimensional design plane and a three-dimensional design space. Furthermore, the correspondence can be managed in parts structure units between two-dimensional design plane data and three-dimensional design space data. 15

In addition, when there are parts and units represented as scattered on a plurality of design planes and design spaces, a user can be notified of the influence of a change in a placement position of 20 a part, etc. on one work plane on other related two-dimensional design planed and three-dimensional design spaces.

Furthermore, an editing process can be interactively performed which checking the 25 consistency. In addition, the operation performed on

a graphic element represented on a design plane/design space can be automatically reflected on another design plane/design space. The three-dimensional consistency such as the parts position can be checked on a two-dimensional design plane.

Furthermore, an editing operation of an optional model at any hierarchical level, optional reference information (placement information, etc.), and a shape on any work plane or space can be performed without switching a model, a work plane, or a work space to be processed.

What is claimed is:

1. A CAD system which processes a two-dimensional
design plane/three-dimensional design space configured
5 by referring to another two-dimensional design
plane/three-dimensional design space, comprising:
 - 10 an intra-model correspondence management unit
managing correspondence between a two-dimensional
design plane and a three-dimensional design space for
the same target; and
 - 15 an inter-model reference management unit managing
reference between models configured by at least one
two-dimensional design plane and three-dimensional
design space for the same target.
2. The CAD system according to claim 1, wherein
said correspondence is a spatial attribute of
each two-dimensional design plane in a model.
- 20 3. The CAD system according to claim 1, further
comprising:
 - 25 an automatic assembly unit generating three-
dimensional reference between a three-dimensional
design space of a first model and a three-dimensional
design space of a second model according to two-

dimensional reference of a plurality of two-dimensional design planes belonging to the first model to a two-dimensional design plane belonging to the second model, correspondence in the first model, and 5 correspondence in the second model.

4. The CAD system according to claim 3, wherein
said automatic assembly unit automatically
assembles a three-dimensional design space belonging
10 to the first model using two-dimensional reference of
a plurality of two-dimensional design planes belonging
to the first model, and the correspondence in the
first model.

15 5. The CAD system according to claim 4, wherein
said automatic assembly unit, sequentially from
a model in a lowest hierarchical level in reference,
determines a placement vector in a referenced-from
three-dimensional design space from correspondence in
20 a referenced-from model determines a reference vector
in a three-dimensional design space of the referenced-to
model from correspondence in a referenced-to model,
generates a conversion matrix of the placement vector
and the reference vector, and assembles a three-
dimensional design space of the referenced-from model
25

based on the conversion matrix.

6. The CAD system according to claim 1, wherein
when one of the two-dimensional reference and the
5 three-dimensional reference is performed between the
models, said inter-model reference management unit
performs other two-dimensional reference and three-
dimensional reference between the models corresponding
to a prior referencing operation.

10

7. The CAD system according to claim 6, wherein
said inter-model reference management unit
automatically performs the other two-dimensional
reference and three-dimensional reference between the
15 models corresponding to the prior referencing
operation.

8. The CAD system according to claim 6, wherein
said inter-model reference management unit
20 performs the other two-dimensional reference and
three-dimensional reference between the models
interactively with a designer corresponding to the
prior referencing operation.

25 9. The CAD system according to claim 6, wherein

5 said inter-model reference management unit
notifies a designer of consistency corresponding to
the prior referencing operation.

5 10. The CAD system according to claim 1, further
comprising

10 a new reference setting unit setting consistent
reference, when new reference is set between a first
design plane/space which is one of a two-dimensional
15 design plane or a three-dimensional design space
belonging to a third model and a second design
plane/space which is one of a two-dimensional design
plane or a three-dimensional design space belonging
to a fourth model, between a two-dimensional design
20 plane and a three-dimensional design space other than
the first design plane/space belonging to the third
model and a two-dimensional design plane and a three-
dimensional design space other than the second design
plane/space belonging to the fourth model based on the
new reference, the correspondence in the third model,
and the correspondence in the fourth model.

25 11. The CAD system according to claim 1, wherein
a plurality of two-dimensional design
planes/three-dimensional design spaces belonging to

the model are specified to be edited based on the correspondence in the model.

12. The CAD system according to claim 1, wherein
5 when an element specified in a two-dimensional
design plane or a three-dimensional design space
belonging to a fifth model is moved to a newly
generated sixth model, said inter-model reference
management unit sets inter-model reference between the
10 fifth model and the sixth model.

13. The CAD system according to claim 12, wherein
15 when said sixth model is generated, said intra-
model correspondence management unit sets intra-model
correspondence of the sixth model.

14. The system according to claim 12, wherein
20 when said sixth model is generated, a designer
is instructed to maintain spatial consistency of each
of the two-dimensional design planes and the three-
dimensional design spaces belonging to the sixth
model.

15. A cooperative system which maintains cooperation
25 of graphics data between a two-dimensional CAD and a

three-dimensional CAD, comprising:

an intra-model correspondence management unit
managing correspondence between a two-dimensional
design plane by a two-dimensional CAD and a three-
5 dimensional design space by a three-dimensional CAD
for the same target; and

10 an inter-model reference management unit managing
reference between models configured by at least one
two-dimensional design plane and three-dimensional
design space for the same target.

16. The cooperative system according to claim 15,
further comprising

15 a three-dimensional reference generation unit
generating three-dimensional reference between a
three-dimensional design space of the first model and
a three-dimensional design space of the second model
according to two-dimensional reference of a plurality
of two-dimensional design planes belonging to a first
20 model to a two-dimensional design plane belonging to
a second model, correspondence in the first model, and
correspondence in the second model.

25 17. The cooperative system according to claim 16,
wherein

5 said automatic assembly unit automatically assembles a three-dimensional design space belonging to the same model using two-dimensional reference of a plurality of two-dimensional design planes belonging to the same model, and the correspondence in the model.

10 18. A CAD system which processes a two-dimensional design plane/three-dimensional design space configured by referring to another two-dimensional design plane/three-dimensional design space, comprising:

15 intra-model correspondence management means for managing correspondence between a two-dimensional design plane and a three-dimensional design space for the same target; and

20 inter-model reference management means for managing reference between models configured by at least one two-dimensional design plane and three-dimensional design space for the same target.

25 19. A cooperative system which maintains cooperation of graphics data between a two-dimensional CAD and a three-dimensional CAD, comprising:

intra-model correspondence management means for managing correspondence between a two-dimensional

design plane by a two-dimensional CAD and a three-dimensional design space by a three-dimensional CAD for the same target; and

5 inter-model reference management means for managing reference between models configured by at least one two-dimensional design plane and three-dimensional design space for the same target.

20. A method of managing CAD data comprising:

10 managing correspondence between a two-dimensional design plane and a three-dimensional design space for the same target; and
15 managing reference between models configured by a two-dimensional design plane and a three-dimensional design space for the same target.

21. The method according to claim 20, wherein
said correspondence is a spatial attribute of each two-dimensional design plane in a model.

20 22. The method according to claim 20, wherein
 three-dimensional reference is set between a three-dimensional design space of a first model and a three-dimensional design space of a second model
25 according to two-dimensional reference of a plurality

of two-dimensional design planes belonging to the first model to a two-dimensional design plane belonging to the second model, correspondence in the first model, and correspondence in the second model.

5

23. A computer-readable storage medium storing a program used to direct a computer to perform:

managing correspondence between a two-dimensional design plane and a three-dimensional design space for
10 the same target; and

managing reference between models configured by a two-dimensional design plane and a three-dimensional design space for the same target.

15

24. The medium storing a program used to direct a computer to perform according to claim 23:

setting three-dimensional reference between a three-dimensional design space of a first model and a three-dimensional design space of a second model
20 according to two-dimensional reference of a plurality of two-dimensional design planes belonging to the first model to a two-dimensional design plane belonging to the second model, correspondence in the first model, and correspondence in the second model;
25 and

automatically assembling a three-dimensional design space belonging to the first model using the three-dimensional reference.

Abstract of the Disclosure

5 A CAD system and a CAD cooperative system maintain correspondence between a two-dimensional
design plane and a three-dimensional design space
(hereinafter referred to as a model), and between
models for the same target. The correspondence
between models is managed by an intra-model
correspondence management unit, and the reference
10 between models is managed by an inter-model reference
management unit. Thus, there can be an interlocking
operation between a two-dimensional design plane and
a three-dimensional design space. furthermore, a
three-dimensional reference can be automatically set
15 for a three-dimensional design space to another model.

F I G. 1

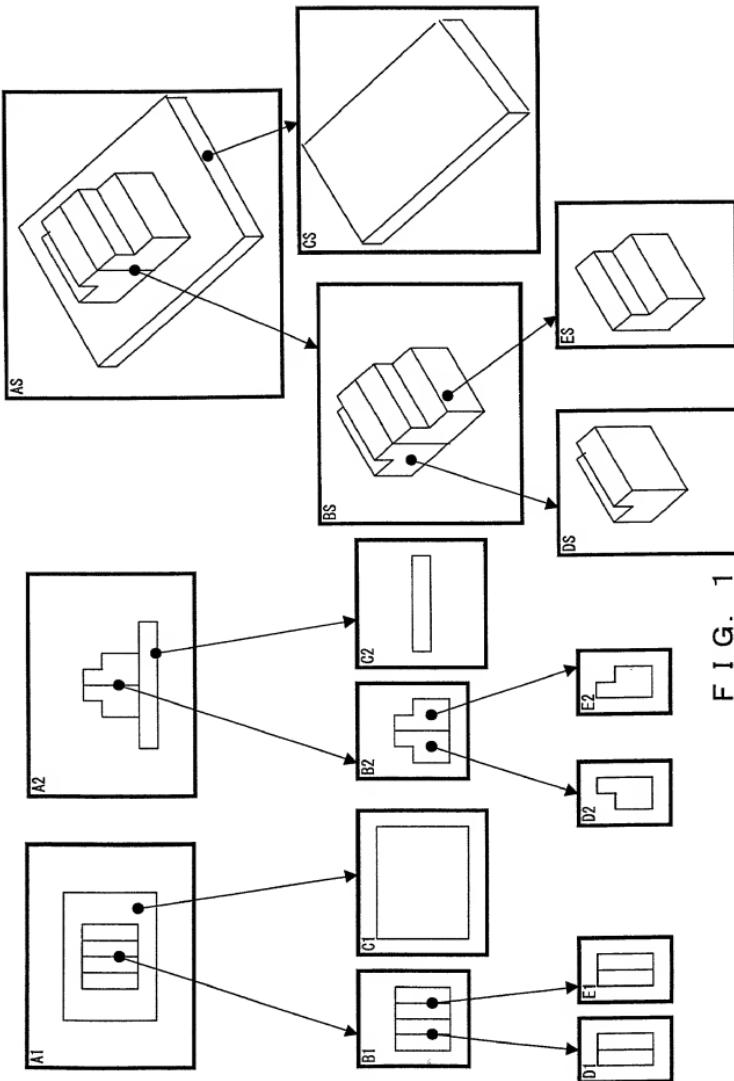
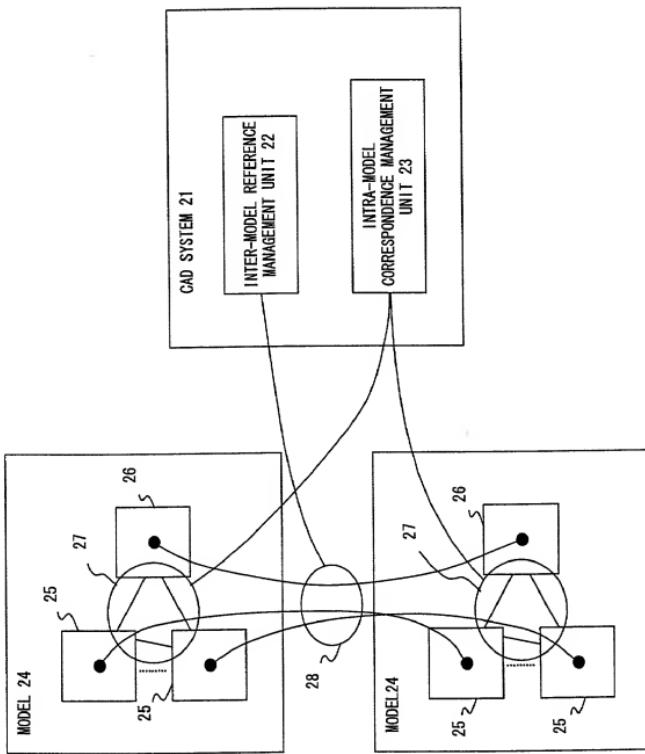


FIG. 2



MODEL INFORMATION

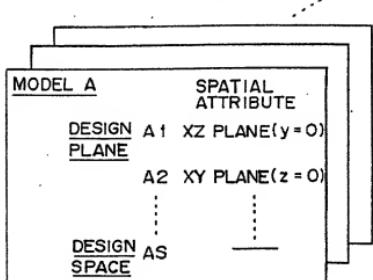


FIG. 3A

MODEL REFERENCE INFORMATION

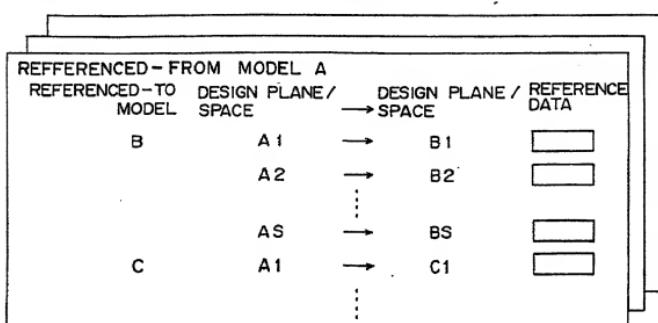


FIG. 3B

MODEL 'D'

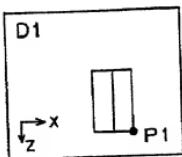


FIG. 4

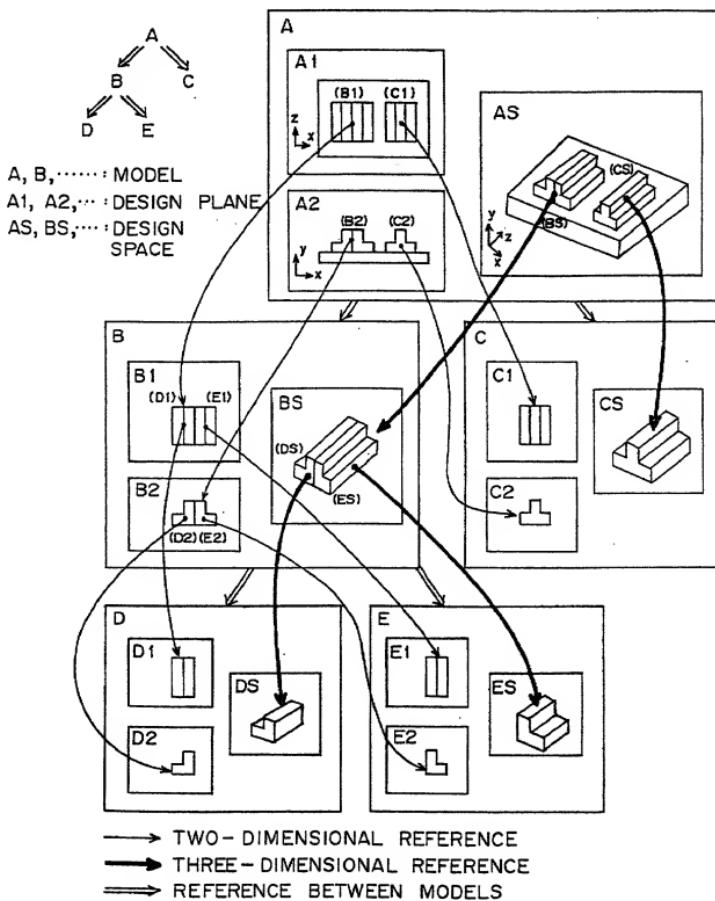


FIG. 5

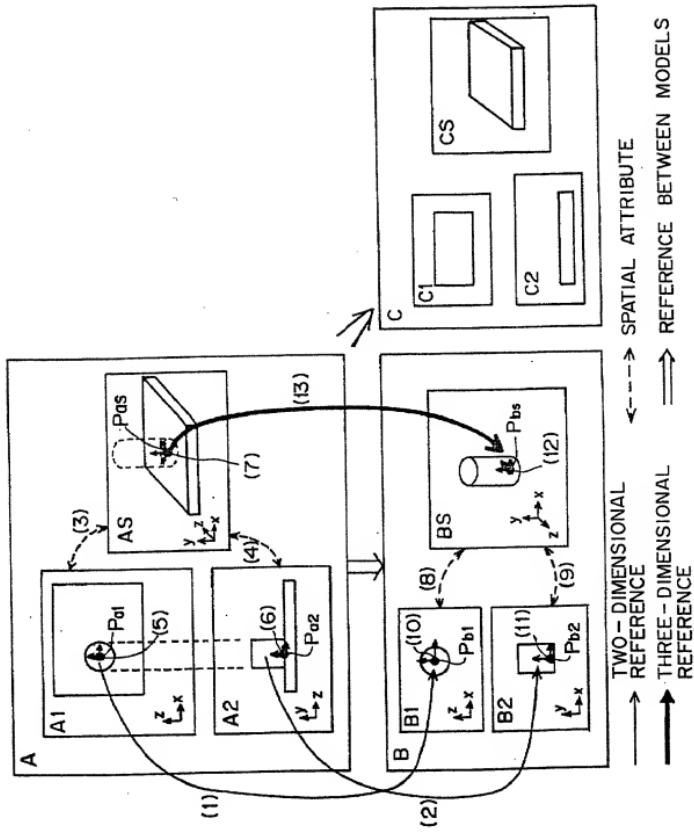
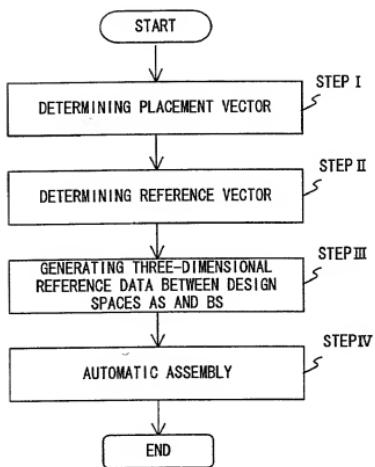


FIG. 6



F I G. 7

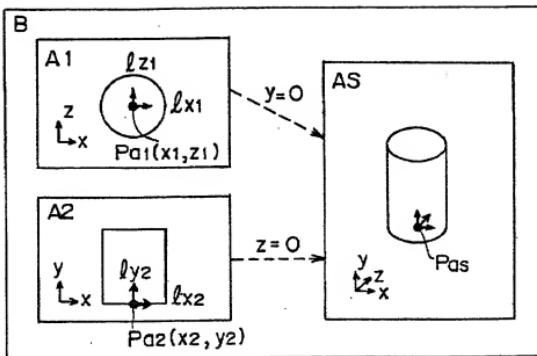


FIG. 8A

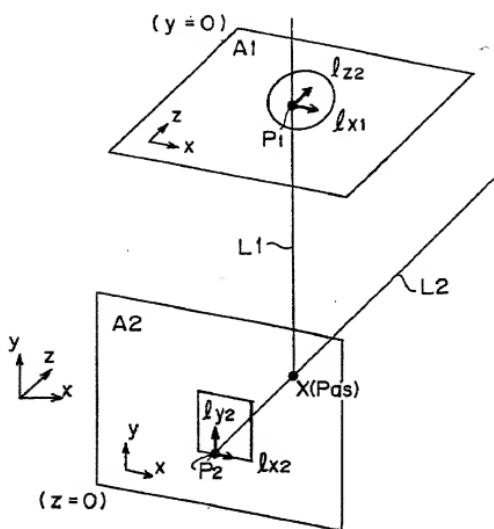
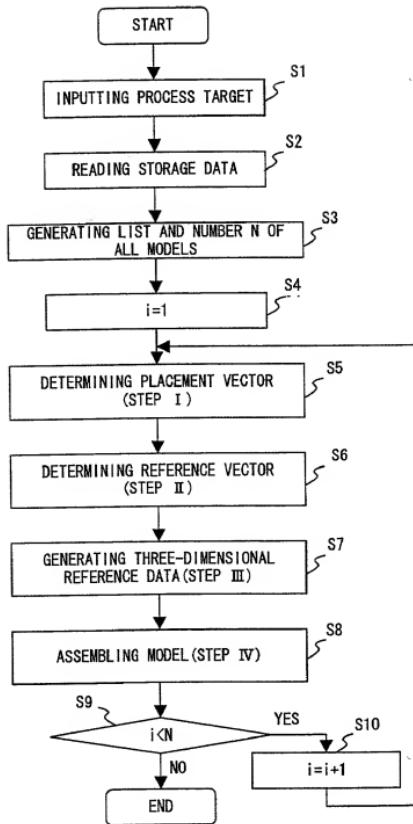


FIG. 8B



F I G. 9

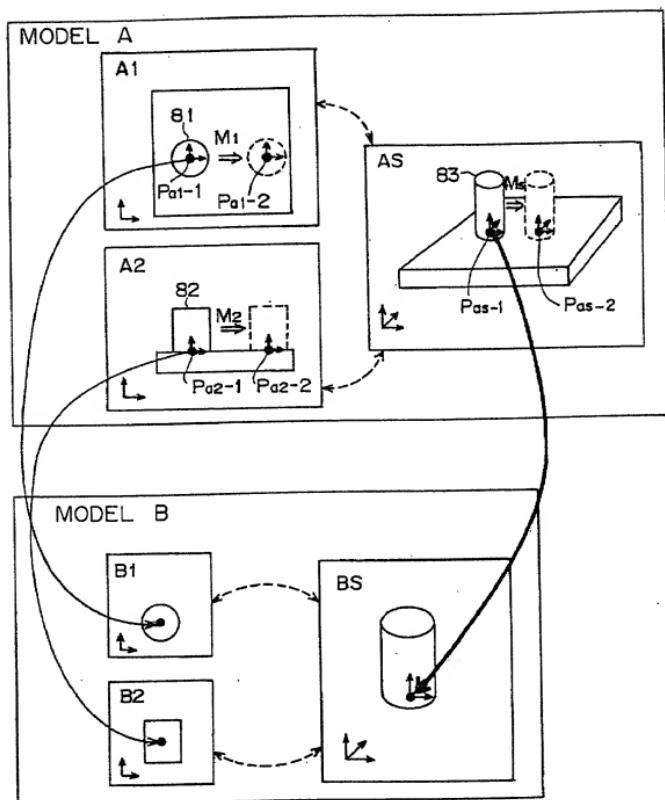


FIG. 10

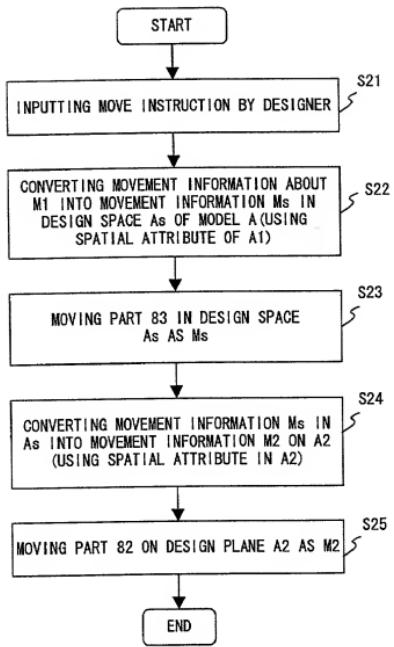


FIG. 11

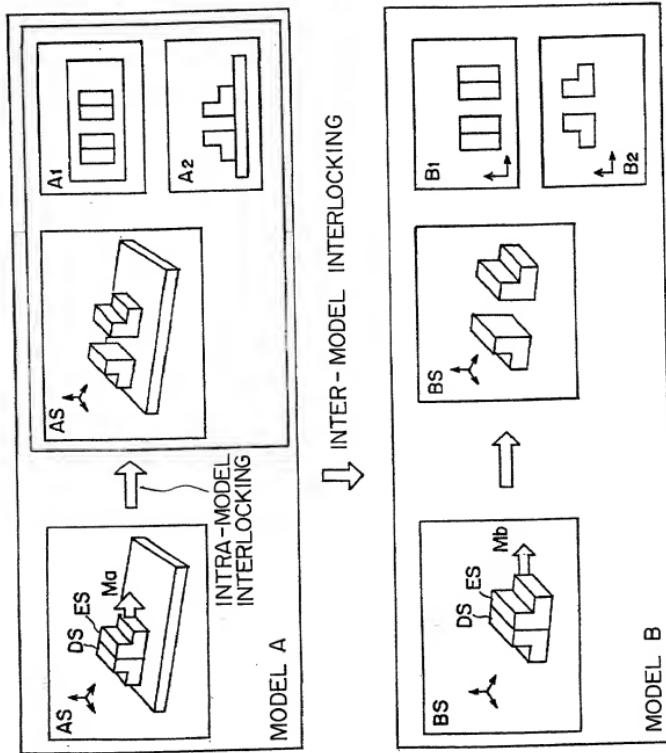


FIG. 12

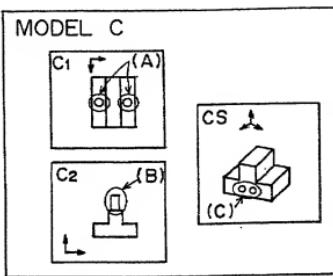
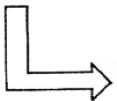
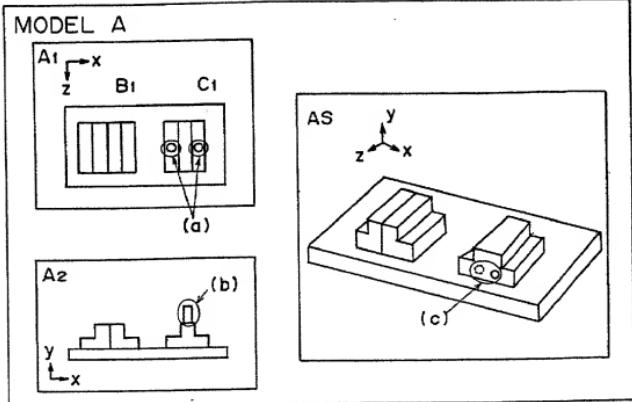


FIG. 13

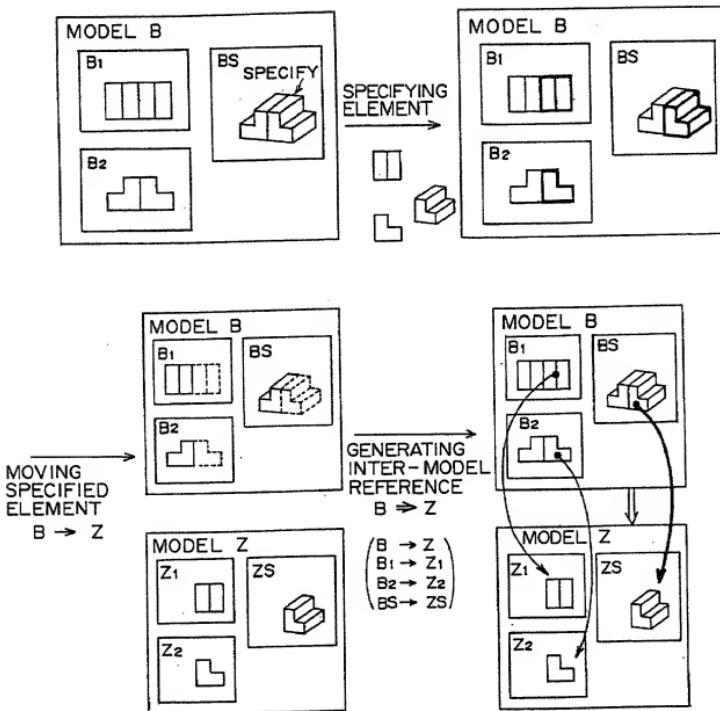
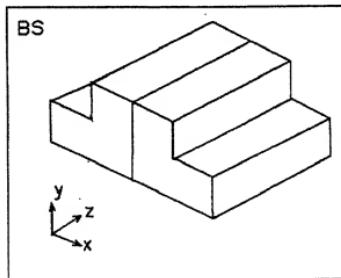
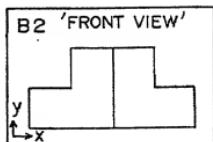
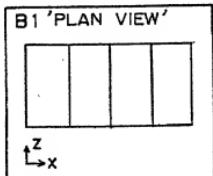


FIG. 14

MODEL B



↓ GENERATION

MODEL Z

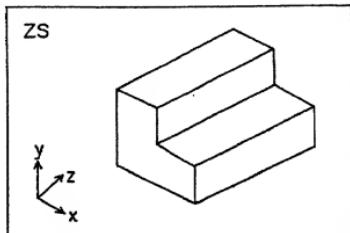
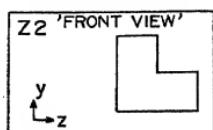
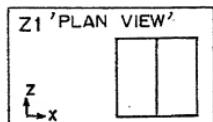
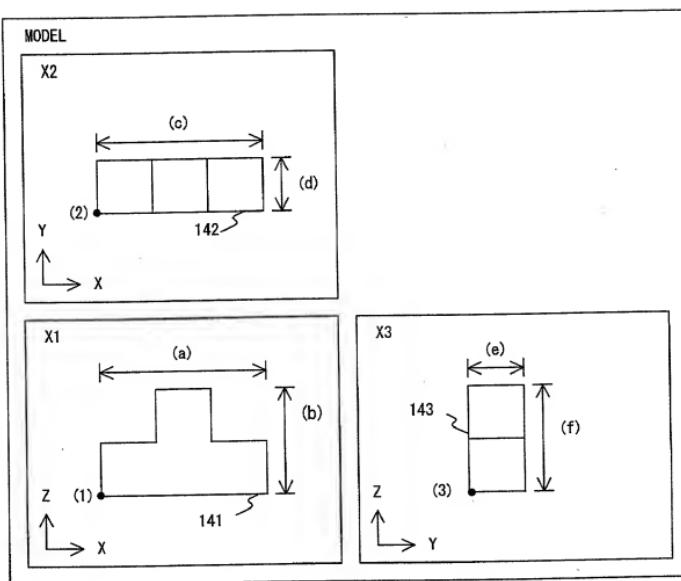


FIG. 15



F I G. 16

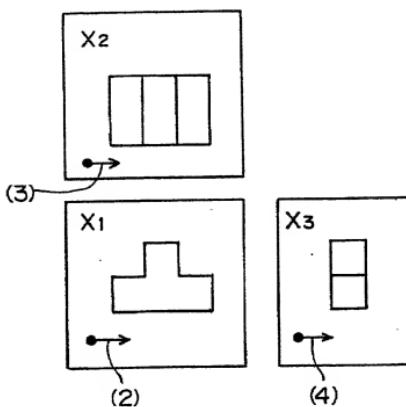
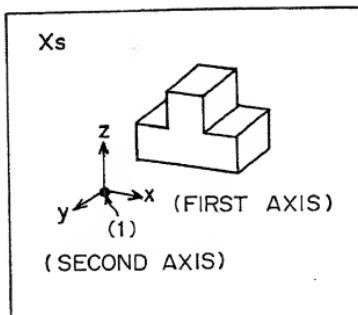
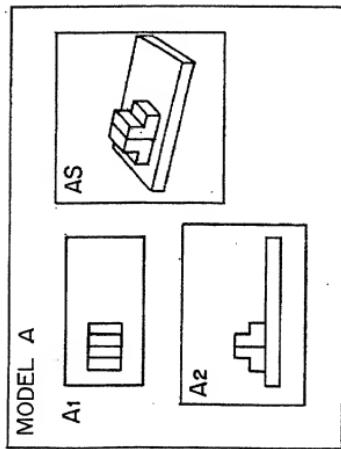
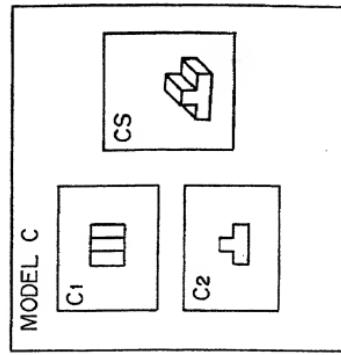


FIG. 17



REFERENCED - TO MODEL
(FROM WHICH MODEL IS PLACED)

FIG. 18

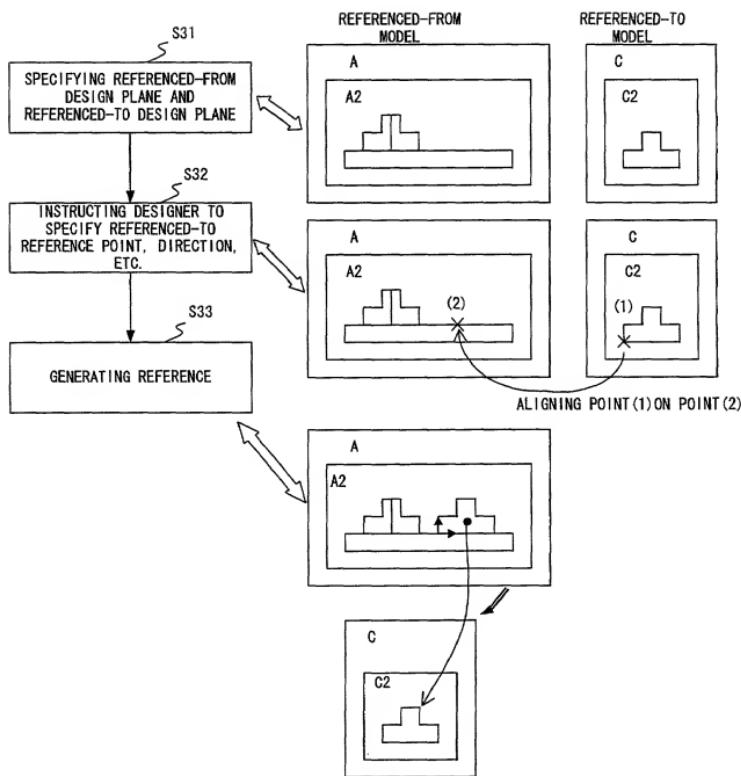


FIG. 19

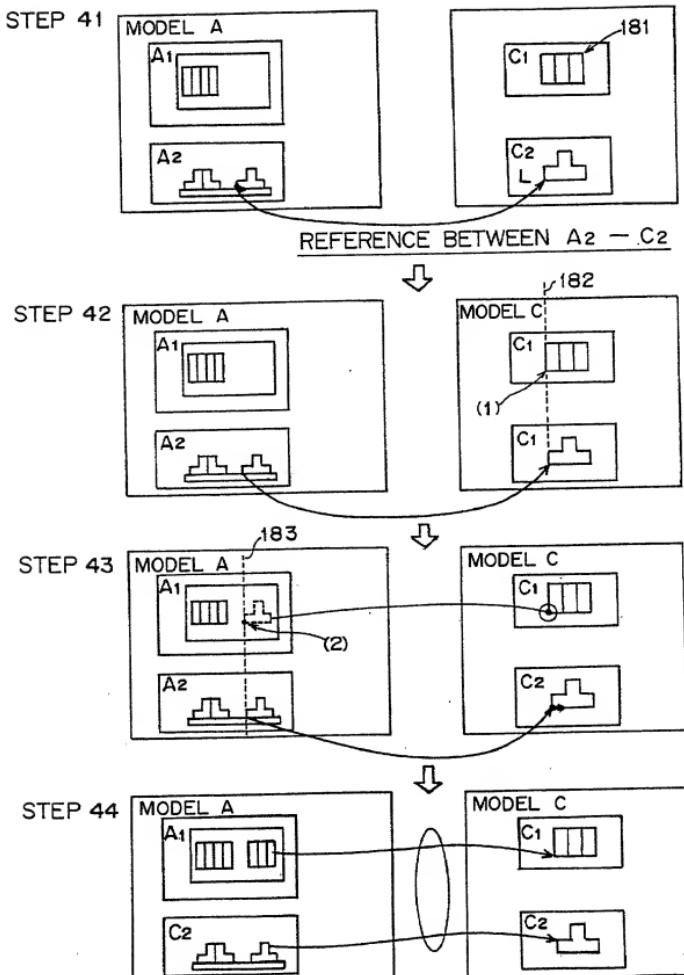


FIG. 20

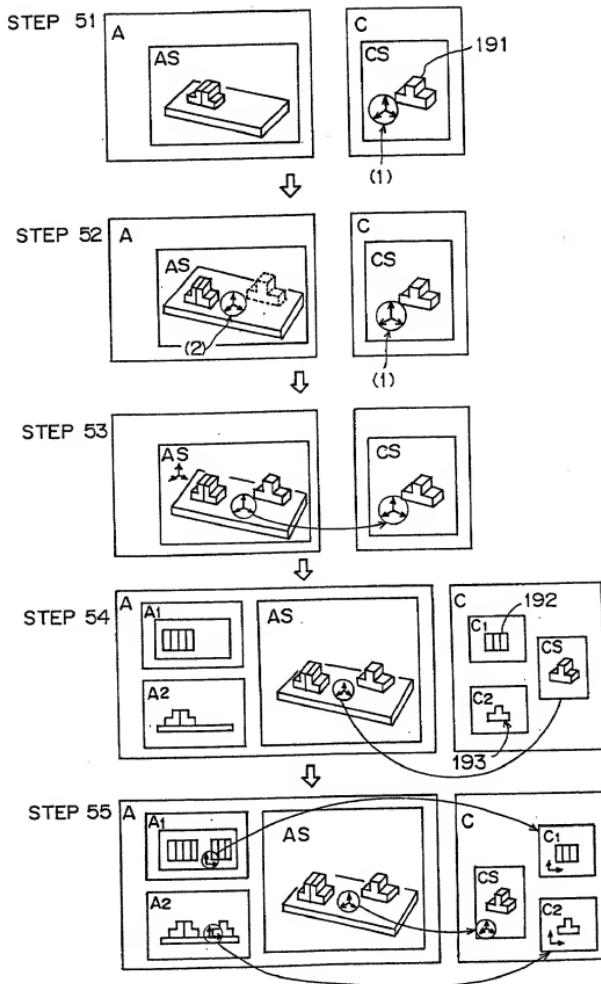


FIG. 21

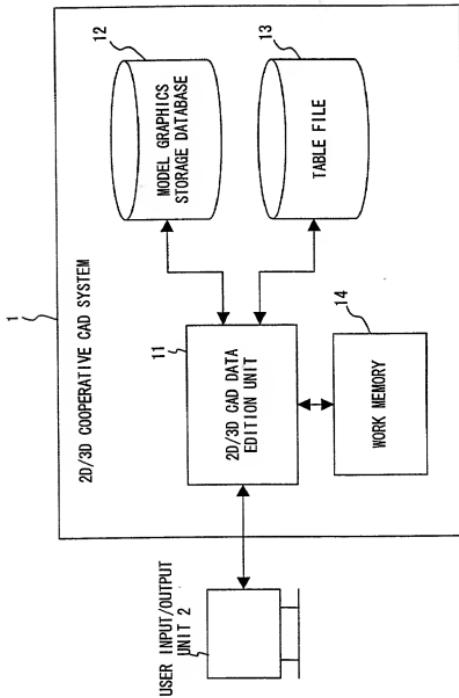


FIG. 22

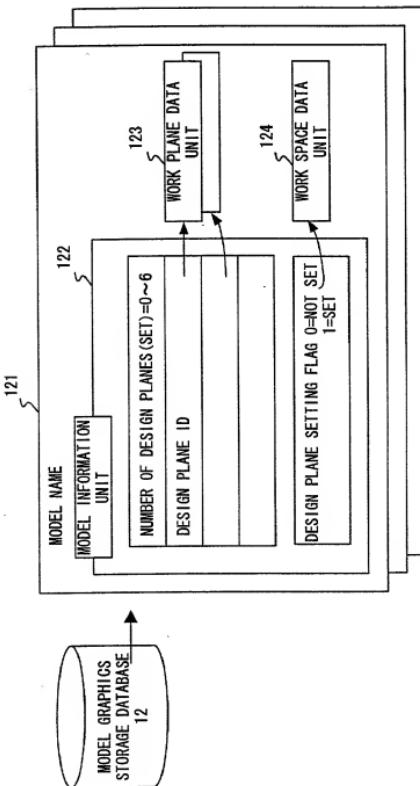


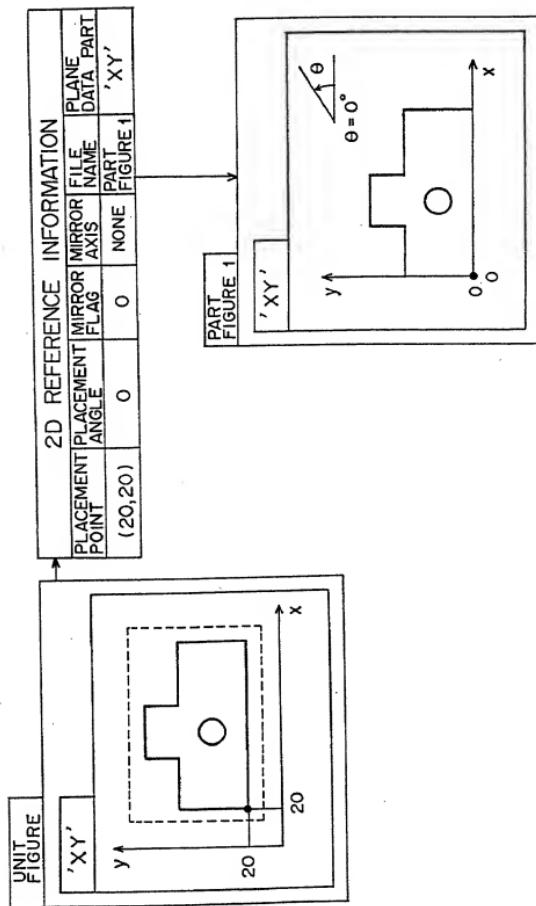
FIG. 23

WORK PLANE DATA UNIT (PLANE NAME='XY1, ID=1)					
GRAPHIC DATA UNIT		GRAPHIC INFORMATION			
GRAPHIC ID		LINE: STARTING POINT, LENGTH, DIRECTION VECTOR			
1					
CIRCLE: CENTER, RADIUS					
2					
S					
SINGLE 2D PARTS STRUCTURE					
DATA UNIT		2D REFERENCE INFORMATION			
PART ID	PLACEMENT POINT (X, Y)	PLACEMENT ANGLE	MIRROR FLAG	MIRROR AXIS	FILE NAME
			1=MIRROR EXISTING 0=MIRROR NOT EXISTING	$\alpha : (\alpha, \beta) \rightarrow (\alpha, -\beta)$ $\beta : (\alpha, \beta) \rightarrow (-\alpha, \beta)$	PLANE DATA UNIT NAME
1	(20, 20)	0°	1/0	α / β	PART 1
2	(40, 100)	10°	1/0	α / β	PART 2
S					'XY' 'XZ'

MODEL FILE NAME		3D REFERENCE INFORMATION			
WORK PLANE DATA		SINGLE 3D PARTS DATA		UNIT	
GRAPHIC DATA		UNIT		UNIT	
GRAPHIC UNIT	GRAPHIC ID	PLACEMENT POINT (X, Y, Z)	FIRST AXIS	SECOND AXIS	FILE NAME
	1	(0, 0, 0)	X AXIS (1, 0, 0)	Y AXIS (0, 1, 0)	PART FIGURE 10
	2	(15, 10, 10)	-Y AXIS (0, -1, 0)	-Z AXIS (0, 0, -1)	PART FIGURE 2
	3				\$

FIG. 25

FIG. 26



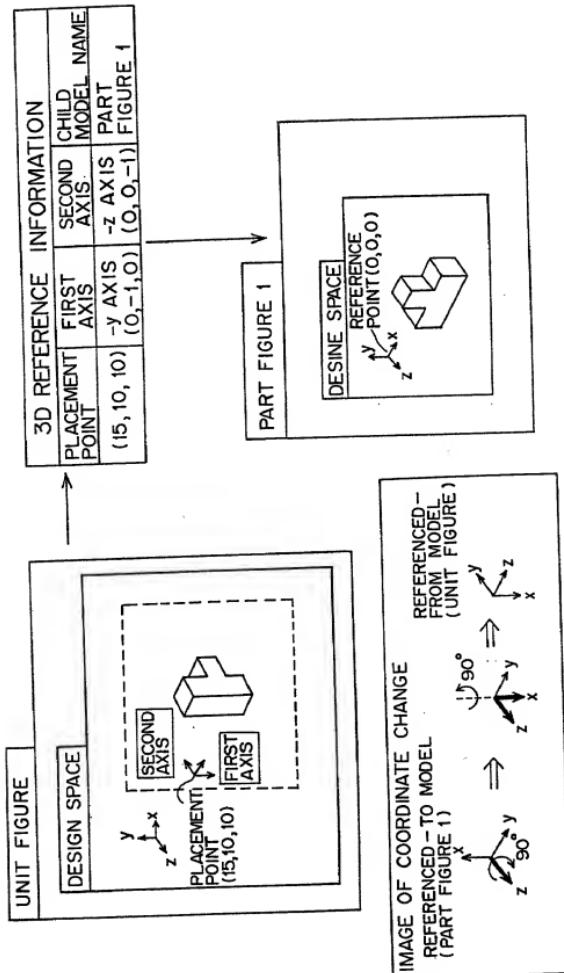


FIG. 27

COORDINATE CORRESPONDENCE
TABLE

PLANE ID	PLANE NAME	FIRST AXIS (α AXIS)	THREE-DIMENSIONAL COORDINATE AXIS VIEWED FROM EACH PLANE	CONVERSION EQUATION INTO 3D SPACE COORDINATE (CONVERSION MATRIX)
1	XY PLANE	X AXIS= (1, 0, 0)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$ NORMAL VECTOR: Z AXIS = (0, 0, 1)
2	-ZY PLANE	-Z AXIS= (0, 0, -1)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$ NORMAL VECTOR: -X AXIS = (-1, 0, 0)
3	X-Z PLANE	X AXIS= (1, 0, 0)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix}$ NORMAL VECTOR: -Y AXIS = (0, -1, 0)
4	ZY PLANE	Z AXIS= (0, 0, 1)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ NORMAL VECTOR: X AXIS= (1, 0, 0)
5	XZ PLANE	X AXIS= (1, 0, 0)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ NORMAL VECTOR: Y AXIS= (0, 1, 0)
6	-XY PLANE	-X AXIS= (-1, 0, 0)		$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix} + \beta \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$ NORMAL VECTOR: -Z AXIS = (0, 0, -1)

CONVERSION TABLE OF EACH
PLANE

3D COORDINATE→2D COORDINATE
(x, y, z) → (α, β)

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} \rightarrow \begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} \rightarrow \begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} \rightarrow \begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

CONVERSION TABLE OF EACH
PLANE

2D COORDINATE→3D COORDINATE
(α, β) → (x, y, z)

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

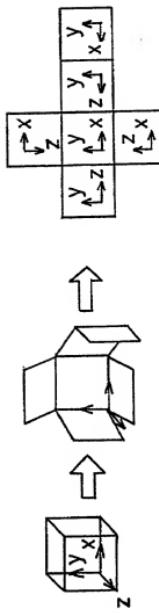


FIG. 29A

PLANE ID

3	1	2	6
4			5

PLANE NAME

X-Z	XY	-ZY	-XY
		XZ	

FIG. 29B

FIG. 29C

α	β	α	β
β	α	β	α
α	β	β	α
β	α	β	α

FIG. 29D

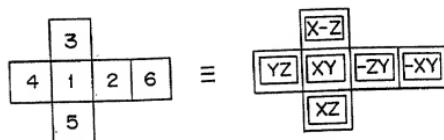


FIG. 30A

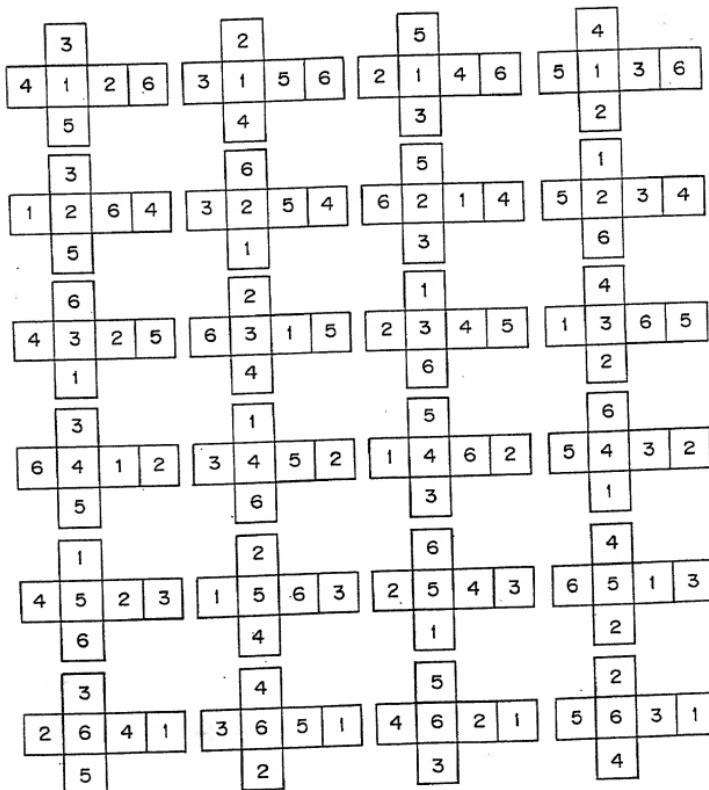
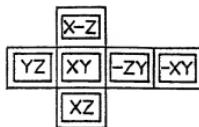


FIG. 30B

PARENT
FIGURE



CHILD FIGURE

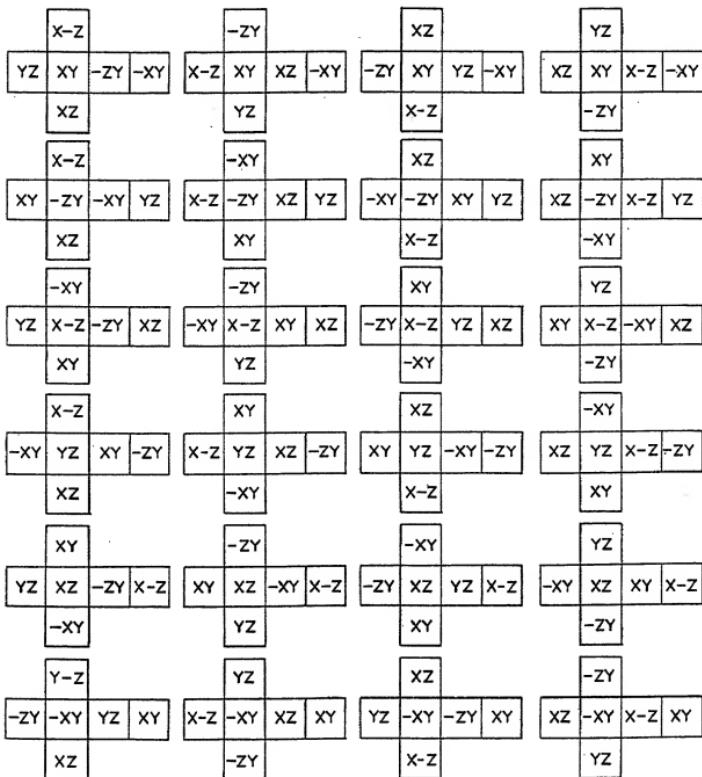
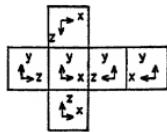


FIG. 31

PARENT FIGURE



CHILD FIGURE

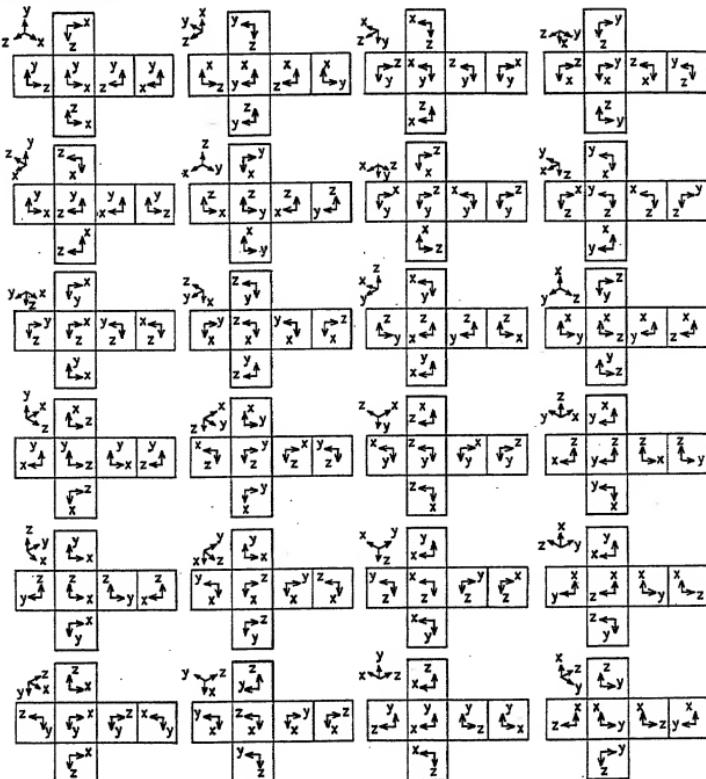


FIG. 32

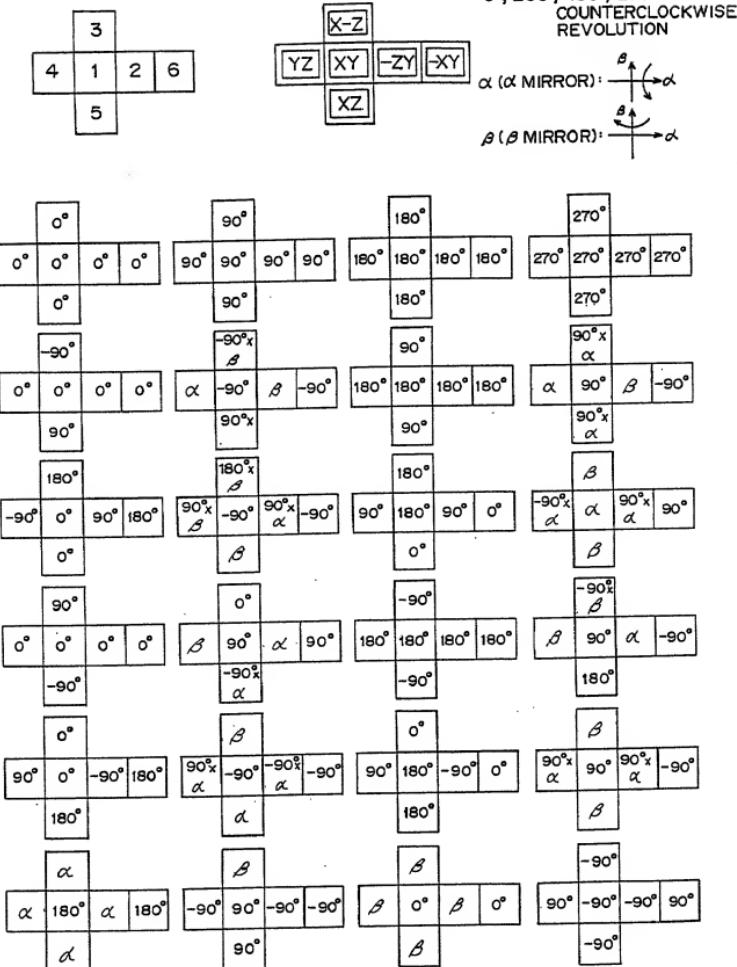


FIG. 33

FIG. 34

ASSEMBLY MANAGEMENT TABLE	
NUMBER OF MODELS=N	
MODEL ID	MODEL NAME
1	TOTAL NUMBER OF FIGURE SETS
2	UNIT FIGURE 1
⋮	⋮
N	PART FIGURE 10

F I G. 3 5

ORDER ID	PARENT MODEL ID	PLACED CHILD MODEL ID	NUMBER OF PLACED MODELS	TERMINAL PROCESS FLAG
A	1	2, 3, 4,	3	0
B	2	5, 6	2	0
C	3	7, 8	2	1
D	4	9, 10	2	0
E	5	11, 12	2	1
F	6	13	1	1
G	9	14	1	1
H	10	15, 16	2	0
I	15	17	1	1

FIG. 36

TERMINAL MODEL TABLE

NUMBER OF TERMINAL
MODELS = N

NUMBER	1	2	3	4	5	6	7	8
MODEL ID	7	8	11	12	13	14	16	17

F I G. 37

2D, 3D PARTS STRUCTURE CORRESPONDENCE TABLE		
PARENTAGE PROCESS ID		
CHILD MODEL ID		
VIEW INTERLOCKING 2D PARTS STRUCTURE DATA UNIT		
NUMBER OF PLACED PLANE		
ID = N		
ID	PARENT FIGURE PLACED PLANE ID	CHILD FIGURE PLACED PLANE ID
1	XY (=1)	X-Z (=3)
	⋮	
N		
3D SPACE PLACEMENT FLAG		
1 = REFERENCE SET, 0 = REFERENCE NOT SET		

F I G. 38

PARENTAGE PROCESS ID		
NUMBER OF CHILD MODELS		
ID	CHILD MODEL ID	CHECK FLAG
1	5	1
2	6	0

F I G. 39

00000000 = 00000000

SPATIAL PLACEMENT INFORMATION TEMP DATA	
3D PLACEMENT POSITION	(x, y, z)
FIRST AXIS	(1, 0, 0)
SECOND AXIS	(0, 1, 0)

FIG. 40

PARALLEL PLANE MANAGEMENT TABLE

COMBINATION ID	PLANE 1	PLANE 2
1	1	6
2	2	4
3	3	5

F I G. 4 1

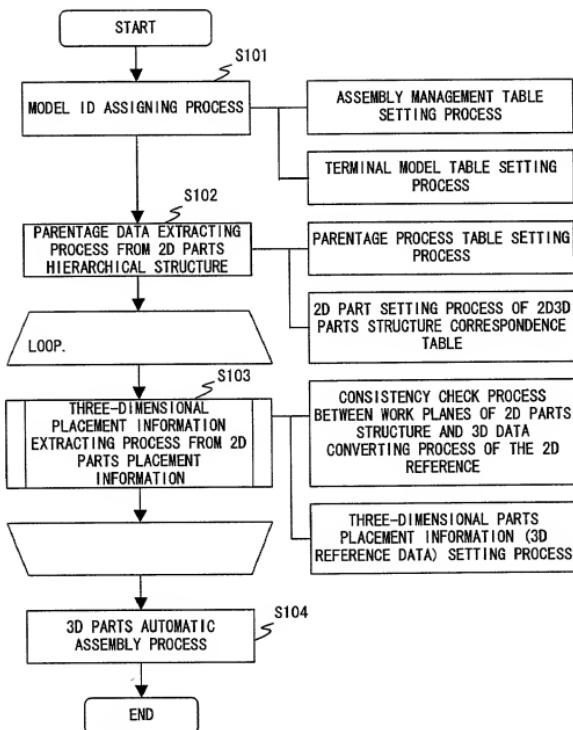


FIG. 42

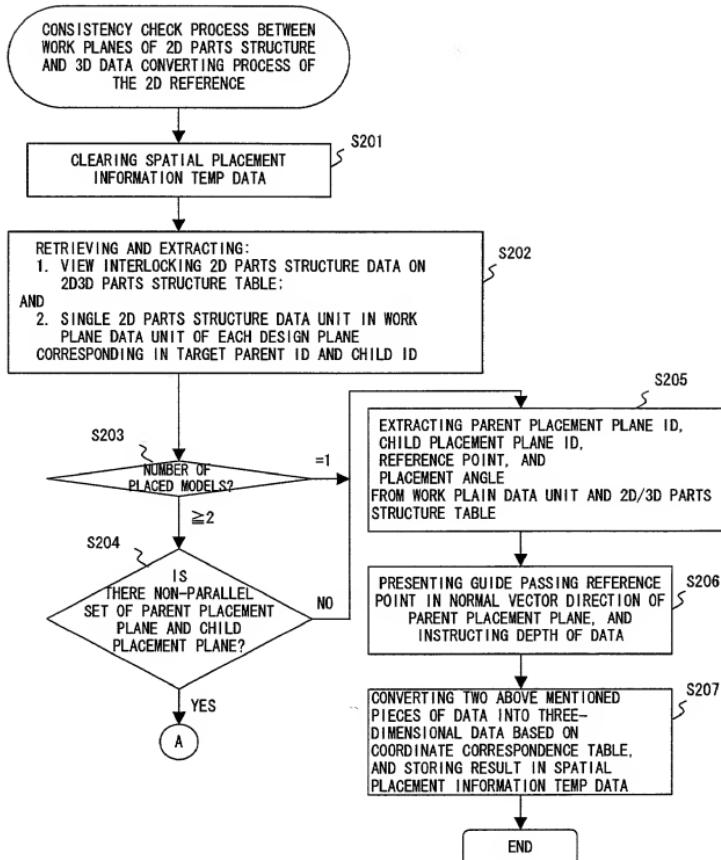
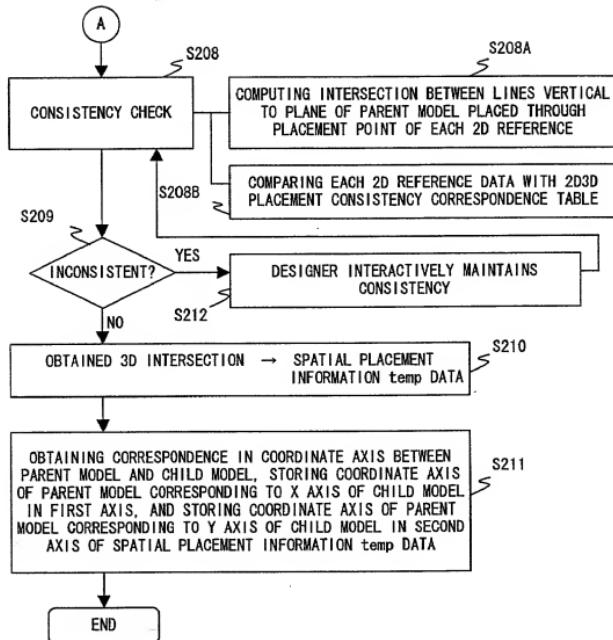
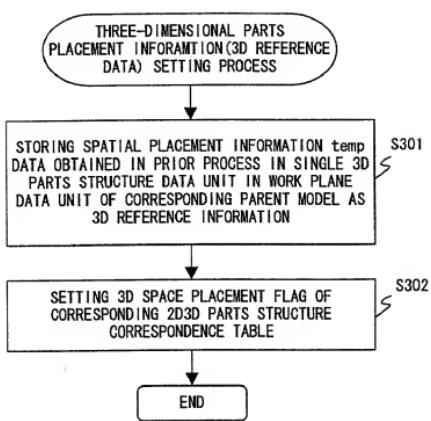


FIG. 43



F I G. 4 4



F I G. 45

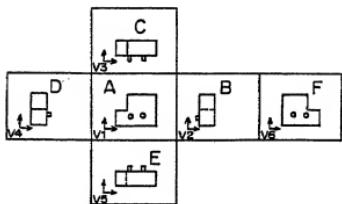


FIG. 46A

	V1	V2	V3	V4	V5	V6
A						
B						
C						
D						
E						
F						

FIG. 46B

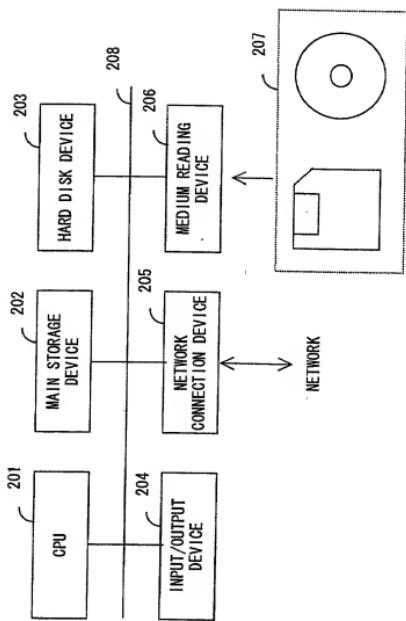
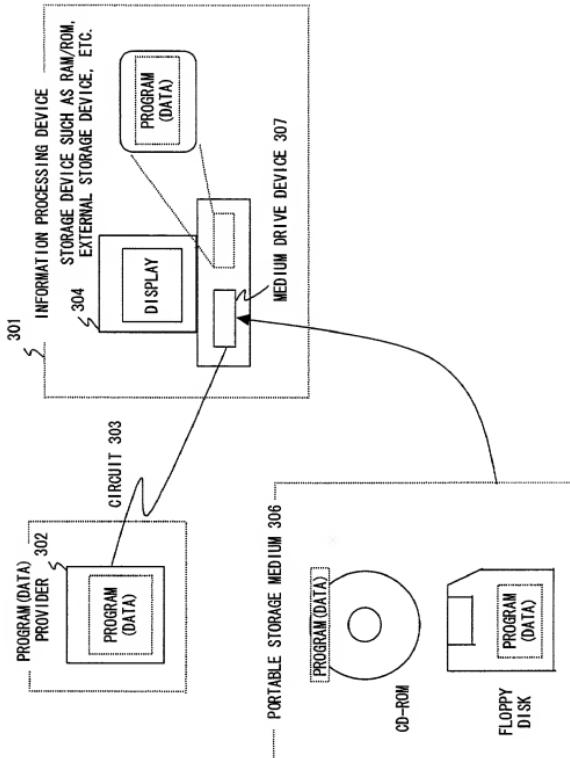


FIG. 47



F 1 G. 4 8

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Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下の私の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、郵便番号、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

CAD SYSTEM, CAD COOPERATIVE SYSTEM,CAD DATA MANAGING METHOD, AND
STORAGE MEDIUM

上記発明の明細書（下記の欄でX印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

月 日に提出され、米国出願番号または特許協定条約出願番号を _____ とし、
(該当する場合) _____ に訂正されました。

was filed on _____
as United States Application Number or
PCT International Application Number
and was amended on
_____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるところ、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid CMB control number.

Japanese Language Declaration (日本語宣言書)

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基づき、米国外の他の少なくとも一ヶ国を指定している特許協力条約365(a)項に基づく国際出願、又は外国での特許出願もしくは発明登録の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または登録出願の外国出願を以下に、神内をマークすることで、示しています。

Prior Foreign Application(s)

外国での先行出願

11-261208

(Number)

(番号)

Japan

(Country)

(国名)

(Number)

(番号)

(Country)

(国名)

私、第35編米国法典119条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

(Application No.)

(Filing Date)

(出願番号)

(出願日)

私は、下記の米国法典第35編120条に基いて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条(c)項に基づく権利をここに主張します。また、本出願の各条項の内容が米国法典第35編112条第3項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願を提出日以降で不出願書の日本国内または特許協力条約国提出日までの期間中に入手された、通常規則法典第37編1条5-6項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

(Application No.)

(Filing Date)

(出願番号)

(出願日)

(Application No.)

(Filing Date)

(出願番号)

(出願日)

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Priority Not Claimed

優先権主張なし

14th/September/1999

(Day/Month/Year Filed)

(出願年月日)

(Day/Month/Year Filed)

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□

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(Application No.)

(出願番号)

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (list name and registration number).

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